# THE RIGGING MAINTENANCE AND INSPECTION OF AIRCRAFT

AERONAUTICAL ENGINEERING SERIES

GROUND ENGINEERS

# THE RIGGING MAINTENANCE AND INSPECTION OF AIRCRAFT

("A" LICENCE)

BY

W. J. C. SPELLER, A.F.R.Ae.S.

*The Air Ministry, whilst accepting no responsibility for the contents of this book, recognizes it as a textbook that should prove to be of value to intending applicants for Ground Engineers' licences*

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# FOREWORD

By H. HASELDEN LEWIS

(*Air Registration Board*)

A Ground Engineer is, primarily, an inspector and, licensed in Category "A," is authorized to inspect and certify an aircraft as being in every way fit for flight. This is a responsibility that cannot, or should not, be undertaken lightly.

A full preparation for the licence entails both practical experience and study. The practical experience should include inspection from various aspects, e.g.—

(1) During the assembly and rigging of the aircraft.

(2) The normal inspection preparatory to signing the daily certificate of safety.

(3) "Schedule" inspection after specified periods of flying.

(4) Investigations after bad landings or other mishaps.

Practical experience of the inspection, on these lines, of the particular types of aircraft for which the applicant desires to be licensed, is essential.

With regard to studies, a knowledge of the Air Navigation Regulations and Directions is essential and this knowledge, once gained, must be kept up to date by noting any amendments subsequently issued.

The applicant will be wise to study also the Airworthiness Handbook (Air Publication 1208) and the handbooks relating to particular types of aircraft issued by the manufacturers.

To the applicant for an "A" licence this book of Mr. Speller's offers much useful information and, read in conjunction with a study of the official regulations and practical experience, will be a great help in qualifying for a licence.

It will also help him to develop, in his work, that "method" which is the hall mark of good inspection.

# PREFACE

An "A" licensee is required to be conversant with the Air Navigation Directions and Statutory Rules and Orders so far as they are applicable to his duties. He is required to have had sufficient practical experience in aircraft maintenance and/or construction and to have a knowledge of all the subjects dealt with in Chapters I and II, and 16 and 17 of Chapter IV herein, these being the minimum requirements. The whole subjects of Chapters III and/or V and/or either or both 18 and 19 (which is usually divided—ashore or afloat) of Chapter IV may be included in, or may form an extension of, a Category "A" licence. The subjects (with the exception of the compass adjustment, which is now a part of Category "X") individually may be made an extension of the whole or any one of the Ground Engineers' licences, Categories "A," "B," "C," "D," and "X."

"A" licences are usually granted in respect of specific kinds and types of aircraft. In this book the subjects have been fully treated; indeed, in many cases they will be found more comprehensive than the requirements of an examining board demand.

This book will be of service to Air Forces, to the staffs and students of Schools, Colleges, Universities, and Training Institutions; personnel in workshops, at aerodromes and seaplane bases; juniors and apprentices and all who desire a sound and thorough knowledge and understanding of everything appertaining to the practical maintenance of heavier-than-air craft.

The author is deeply indebted to Messrs. Bendix, Ltd., whose help in the preparation of the chapter dealing with brakes has been invaluable, also to Messrs. G. Dowty and R. H. Bound, for the chapter on hydraulic actuating equipment. Thanks are due to Mr. V. L. Maniez for his help in connection with the revision. Acknowledgment is also to be made of the courtesy and assistance received from Messrs. Reid and Sigrist, Graviner, Ltd., The Sperry Gyroscope Co., Ltd., and Messrs. de Havilland, Ltd.

# CONTENTS

## CHAPTER V

## INSTRUMENTS: METHODS OF INSPECTING AND TESTING THE INSTALLATION



## CHAPTER VI

## GENERAL SERVICE ELECTRICAL INSTALLATION INCLUDING CONTINUITY AND INSULATION TESTS



## APPENDICES



## INSET

# THE RIGGING MAINTENANCE AND INSPECTION OF AIRCRAFT

BY W. J. C. SPELLER

## CHAPTER I

## 1. ASSEMBLY OF AIRCRAFT STRUCTURE AND RIGGING ADJUSTMENT AND CHECK

### Fuselage Rigging Adjustment and Check

THE first component in the assembly of a landplane is the fuselage, and it is assumed here that this component is correctly assembled and truly

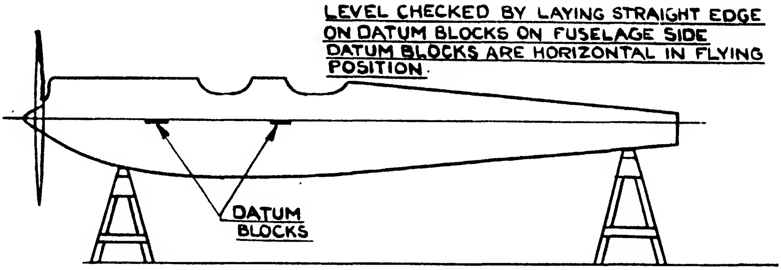


FIG. 1. RIGGING POSITION

rigged. The fuselage should be placed on trestles and arranged longitudinally and laterally approximately level, allowing sufficient height to enable the undercarriage to be attached. The supporting trestles must be placed under the jacking blocks, which are usually situated near the front undercarriage struts, and at the rear of the fuselage near the tail skid. The fuselage when correctly positioned for assembly of the superstructure is said to be in the "rigging position" (see Fig. 1).

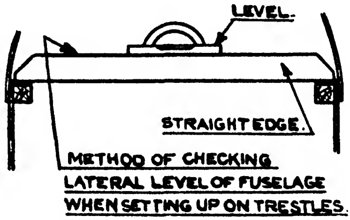


FIG. 2. FIXED LEVELLING BLOCKS

The "rigging position" is indicated in the rigging notes contained in the maker's handbook, or on the rigging diagram supplied for each type of aircraft. Datum lines or fixed levelling blocks (see Figs. 1 and 2) are now provided on all modern aircraft, and they enable the rigger easily to set the fuselage into correct position both longitudinally and laterally. When level the fuselage should be securely anchored.

### Undercarriage

Now attach the undercarriage, which is usually rigged so as to be symmetrical about the centre line of the fuselage both in front and plan view. Undercarriages vary in design and construction, for small aircraft they usually consist of two side struts forming a "V" each side, axles, shock-absorbing devices, and cross bracings of flexible cable or streamline wire. For truing up the undercarriage the cross bracings should be adjusted to be equal in length; check this by the use of trammels, next drop plumb lines from the longerons on to the axle tube, and measure to the inside of the wheel flanges (see Fig. 3).

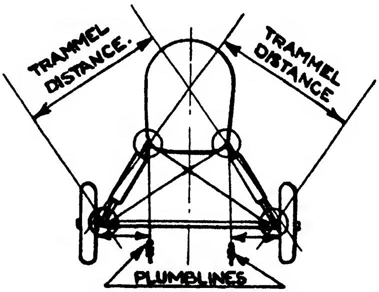

Fig. 3. Truing Up Undercarriage

When equal in length on each side the axle is central. Another method of checking can be made (1) from the outside of the wheel hub flange to some point in the centre of the fuselage between the undercarriage and sternpost, and (2) from the axle cap to some important fitting on the underside of the lower planes.

### Centre Section

This is usually the next component to be erected, and if the struts are wooden members they must be carefully fitted and "bedded" in the strut sockets.

This unit can be roughly assembled on the ground and lifted into position. The loose ends of the struts are next attached to their respective fittings on the fuselage, and the ends of the bracing wires and struts are connected up.

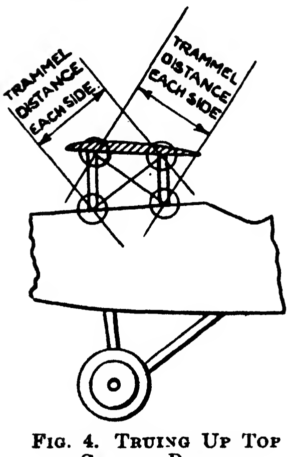

Fig. 4. Truing Up Top Centre Plane

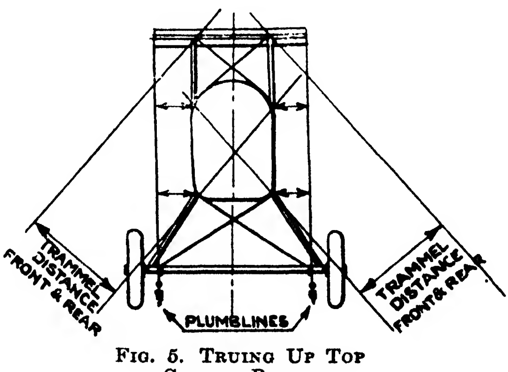

Fig. 5. Truing Up Top Centre Plane

### Truing Up the Centre Section

To true up the centre section, trammel the front, side, and rear diagonals (see Figs. 4 and 5) until the leading edge is horizontal and symmetrical

about the vertical centre line of the aeroplane, and is correctly (if applicable) staggered relative to the bottom plane position. The bracing wires are to brace the structure correctly and must not be used otherwise to pull a plane into its correct position or incidence.

### Checking the Centre Section After Rigging

Drop plumb lines from the spar wing attachment fittings, front and rear, right and left sides, and measure to the fuselage. The measurement should be the same each side. To check the stagger, drop plumb lines over the leading edge of the top centre section and measure to the leading edge of the stub wing, or from the existing line from the top wing attachment fittings, measure to the lower wing attachment fittings on the fuselage. These dimensions should be equal on both sides and correct with the requirement laid down in the aircraft rigging diagram.

### Attaching Main Planes (Medium biplane two-bay types)

The lower plane should be placed in a position with its chord vertical, care being taken not to damage the fabric or protective coating on the leading edge. Next fit the interplane struts, taking special precautions, where the diameters and lengths of the struts vary, that they are in their correct positions. The upper main plane should then be positioned to the lower plane so that the interplane struts may be attached. The bracing wires should then be joined to their respective fork ends and great care taken to see that these attachments are in their correct positions. Remember that the flying wires (which may be duplicated) are usually of a heavier gauge than the landing wires. Enter the wires carefully into the fork ends and commence turning, noting that the same number of threads are engaged at each end.

Having now boxed up the planes into a fairly rigid structure, lift into position, connect up the spar attachments, and then join up the bracing wires for the inner bay, first the inner landing wires from the top centre section to the bottom of the inner pair of interplane struts. Adopt the same method for each side to complete the assembly of the main planes. For method of mounting the main planes of seaplanes having a single set of struts, and for the larger multi-bay machines, see Chapter IV, "Rigging and Assembly of Flying Boats."

### Truing Up the Main Planes

In most cases the aircraft manufacturers provide levelling, incidence, and dihedral boards (see Figs. 6 and 7), to enable a rapid and accurate

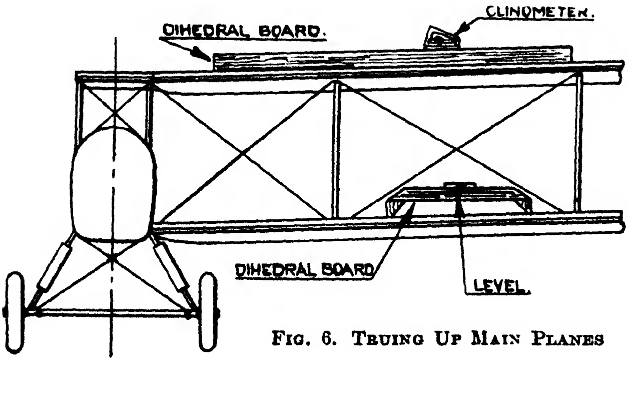


FIG. 6. TRUING UP MAIN PLANES

check to be made of the incidence and dihedral angles. If these special boards are not available, angles should be checked by using a straight edge and clinometer (also shown in Figs. 6 and 7).

The dihedral angle of the main plane is fixed by the adjustment of the front landing wires, and is checked by means of dihedral board or straight edge and clinometer over the front spar.

The stagger is adjusted by the cross bracing between the front and rear interplane struts, and is checked by measuring horizontally the distance of a plumb line dropped from the leading edge of the upper main plane to the leading edge of the lower main plane (see Fig. 8).

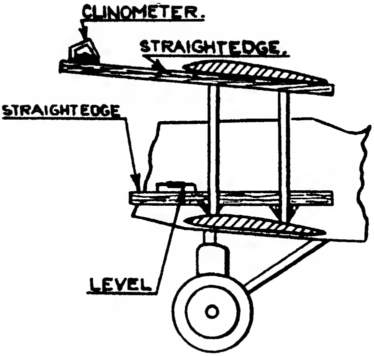


FIG. 7. TRUING UP MAIN PLANES

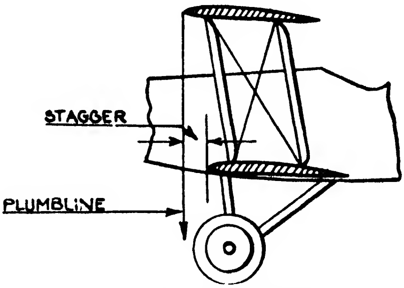


FIG. 8. MEASURING STAGGER

The incidence of the main planes is adjusted chiefly by means of the rear landing wires, in conjunction with the incidence bracing between the front and rear interplane struts. The incidence is checked by using the special board with a level, or by means of a clinometer resting in a straight edge which is held up under the main plane and along one of the ribs (see Fig. 6).

When the dihedral and incidence angles, on each side, and the stagger are all correct, the planes have to be checked to see that they are symmetrical with the fuselage by measuring from points at the upper and lower outer front strut fitting to the stern post and the centre of the airscrew shaft.

### Truing Up the Tail Unit

The tail plane is laterally horizontal and is symmetrical about the centre line of the fuselage. This component is checked transversely with a straight-edge and spirit level (see Fig. 9), if the spars are tapered packing blocks are necessary. The incidence must be checked by using a special board and a clinometer (see Fig. 10), and if the aircraft is fitted with an adjustable tail plane the incidence in the upper and lower positions must also be checked.

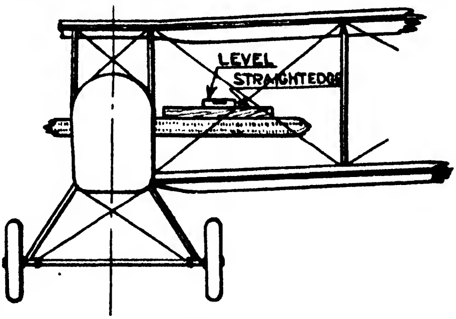


FIG. 9. TRUING UP TAIL UNIT

The rudder is checked vertically by dropping a plumb line over each side. Pack out against the top rib and measure between the line and the lower trailing edge of the rudder. The longitudinal centre line of the fin may coincide with the centre line of the aircraft, or be offset to right or left to give slight rudder effect. This must be checked to the dimension or angle given in the maker's handbook.

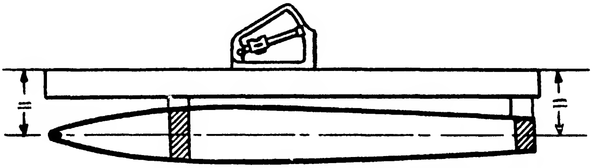

FIG. 10. MEASURING TAIL PLANE INCIDENCE

## 2. CONTROLS: ADJUSTMENT AND CHECK

### General

The safety of an aircraft in flight is directly dependent upon the correct and adequate functioning of its flying controls. Every precaution must, therefore, be taken by the inspector to ensure the correctness of each element forming part of such a system, in addition to ensuring the adequacy of its installation, functioning, and range of operation. As meticulous care is essential and no individual infallible, the duplication of final inspection called for hereunder must not, in any circumstance, be departed from.

### Control Assembly

The inspection of all aircraft controls must be duplicated, first as an operation during assembly of the aircraft, and, secondly, as part of the inspection immediately preceding flight. These two stages of inspection may not, in any circumstances, be carried out by the same individual.

IMPORTANT. It must be clearly realized that such duplicate inspection must be carried out invariably after all adjustments have been made. Not only has the functioning to be checked, but each separate control must be followed through from end to end and a careful examination made of all joints, junctions, and locking devices. If dismantling or any further adjustment of the controls is carried out thereafter, the duplicate inspection must be repeated.

### Flying Controls

An aeroplane is controlled by means of the following control surfaces—Ailerons, Elevators, Rudders.

*The Ailerons* control the aeroplane laterally, or, in other words, they tend to make the aeroplane rotate round the axis of the fuselage (or hull in the case of a flying boat).

If the control stick is moved to the right or the pilot's control wheel turned to the right, the right ailerons must come *up*, and correspondingly the left ailerons go *down*.

The effect of this is to decrease the lift on the right planes and to increase that on the left planes, with the result that the machine banks to the right. Similarly, if the stick is pushed or the wheel turned to the left, the machine banks to the left.

*The Elevators* control the fore and aft movements of the machine, that is, they move the machine in a path at right angles to the planes. If the machine is flying level, and the pilot's control column is pulled back, the elevators are raised, the tail drops, and the nose rises. If the pilot's control column is pushed forward, the elevators go down, the tail rises, and the nose drops.

*The Rudder* (or rudders) swings the machine along a path parallel with that of the main planes. If the right rudder-bar or rudder pedal is pressed forward, the rudder moves to the right, the tail swings to the left, and the nose of the machine swings to the right. If the left rudder-bar or rudder pedal is pressed forward, the rudder moves to the left, the tail swings to the right and the nose of the machine swings to the left.

## Variable Tail Plane

The tail incidence is usually operated by means of a hand wheel or sometimes a lever in the pilot's cockpit, and to increase the incidence of the tail plane the top rim of the hand wheel is pushed forward, the incidence is decreased by winding the wheel backwards. The directional control of this unit is similar to the elevator control.

## Flying Controls—Adjustment and Check

After assembling the aerofoils and coupling up the controls, adjustments should be made so that the cables and other parts are fairly taut, but work without undue stiffness. All control cables, chains, rods, and levers should be carefully inspected to ascertain that these parts are in good condition and bear evidence of prior approval, and that all unions, joints, and attachments whatsoever throughout the entire system are properly and effectively locked. The flying control systems of modern aircraft are usually operated by means of extra flexible stranded cable of $7 \times 19$ construction, there being seven strands each containing nineteen wires.

It is often necessary to fit new cables, and care must be taken that the splicing is in accordance with standard requirements. When a splice is made round a thimble the cable must be gripped tightly by means of a temporary serving; $4\frac{1}{2}$ tucks are required, the splices are whipped with waxed thread. On marine aircraft the whipping is carried further up the splice than on landplanes to prevent ingress of sea water and deter corrosion. The waxed cord must be removed from time to time to allow thorough inspection of the splice. After splicing, all cables must be stretched by applying a tensile load of 50 per cent of the breaking load of the cable.

When roller chains form part of the flying control system they must be of an approved type, and should it become necessary to replace any parts or attachment fittings, the complete chain unit must be proof loaded to one-third of the ultimate load specified by the aircraft manufacturers.

### Ailerons

In order to allow for the stretch of the cables when under load, ailerons are sometimes given an initial droop, the trailing edge of the aileron being set below the trailing edge of the wing. This droop is the measured difference between the trailing edge line of the wing and the trailing edge line of the aileron. Care must be taken to ensure that the control column is central when checking the amount of aileron droop; similarly the control column must always be central when adjusting the ailerons (the column is not always fore-and-aft vertical, for on some types of aircraft it is set forward of the vertical position, while on others it may be set aft).

The maker's handbook or control system diagram must be carefully studied when making adjustments; this matter is very important and applies to all flying controls. Limits of travels must be checked, and it is advisable to record the measurements in a simple form (see Fig. 11). Particular care is necessary when the balanced or Frise type ailerons are fitted, to ensure that the maximum travel is not exceeded. All control pulleys must be in proper alignment. Guards must be quite clear but must be close enough to prevent the cables riding off the pulleys or the chains off the sprockets. Chains and sprocket teeth, and sprocket and pulley bearings, must be kept clean and lubricated. The control wires or

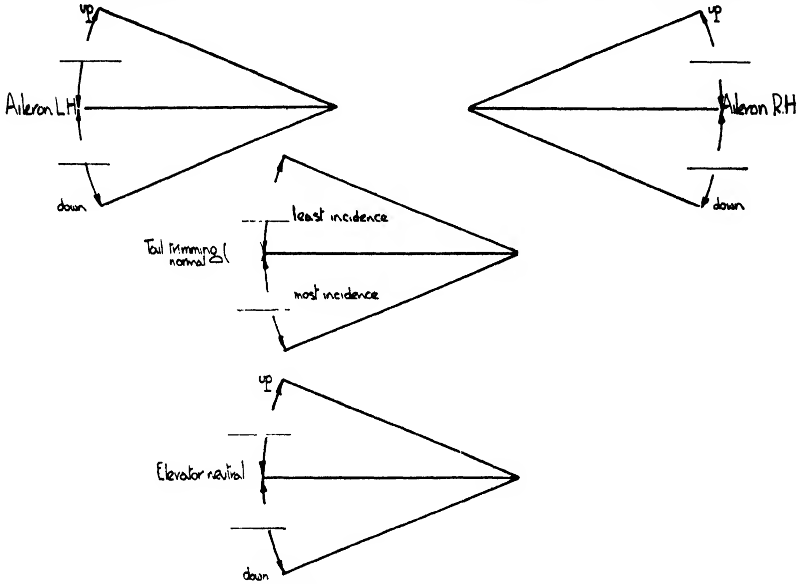


FIG. 11. MOVEMENTS OF CONTROL SURFACES

cables must not be unduly slack; at the same time they should not be over-tight, but should work smoothly throughout the whole of their run. It is advisable during the course of inspection to have the control column and the rudder bar held while an attempt is made to move the various control surfaces, due care being exercised as to the degree of load imposed and as to how and where the individual surfaces are grasped during this test.

## ELEVATORS

When checking the elevators the control column must be central transversely; it is not, however, always required to be vertical as viewed in side elevation, and this fact must be carefully noted by the rigger, who must observe the instructions on the maker's rigging diagram. It is essential that the tail plane incidence be adjusted to normal position and the elevators set in a continuous line with the tail plane. After correct tensioning of the control wires or cables the elevator must be tested for functioning at all tail plane settings, and at the same time the rudders should be operated to make certain that they do not foul the elevators. The control

column's forward stop must be set to allow the correct amount of downward travel, but care must be taken to ensure that corners of the elevator spars do not come in contact with the tail plane rear spar. The travels of the elevator must be strictly in accordance with the design requirements.

RUDDER

When adjusting the rudder controls, care must be taken that the rudder bar or rudder pedals are set at right angles to the fore and aft line of the aircraft, the rudder being central and vertical. The rudder stops must be positioned to allow the correct travel. The rudder controls should just be taut and should work smoothly throughout their run.

TAIL TRIMMING GEAR

It is very important to check the normal incidence, and at the same time to make certain that the indicator position synchronizes. This should again be checked at the maximum upward and downward positions.

The run of controls must be carefully inspected and directional functioning tested after any adjustments have been carried out.

### Trimming Devices

Although, with the three main controls explained above, the pilot has complete control of his aircraft at all times, it is desirable to relieve him as far as possible of the effort of flying. This is done by enabling him to set his controls in such a way that the aeroplane will continue to maintain the required speed and attitude with a minimum of control. To adjust the fore and aft trim of the aircraft, the tail plane may be hinged at one edge, the other edge being raised or lowered by a mechanism (usually a screw jack) operated from the cockpit. The tail plane incidence can thus be altered in flight giving the right amount of lift to the tail to bring the aircraft level. Check the maximum and minimum incidence of tail plane and compare with rigging diagram and verify that position and movement of tail plane is in accordance with that of pilot's control and its index plate. The top of the rim of the control hand wheel should move forward to increase the incidence and make the aeroplane "nose heavy." Another system involves the use of "trimming tabs" on the trailing edges of the elevators. When the tabs are moved downwards the air pressure acting upon them causes the elevators themselves to be moved upwards and the nose of the aircraft to rise. Check that the travel each side of the neutral position is the same and that the trailing edge of the tab moves up when the control is operated in the "nose heavy" direction.

### Rudder

The swirl imparted to the slip-stream, by the rotating airscrew, affects the fin and rudder surfaces, and tends to turn the machine. To counteract this, it is usual to off-set the fin, or bias the rudder, by a spring. Alternatively, a trimming tab may be fitted to the rudder; the tab moves in the opposite direction to that in which it is desired to turn the rudder.

## 3. CORRECTION OF FAULTS EXPERIENCED IN FLIGHT

(i) Tendency to fly one wing low.
(ii) When an aircraft does not fly straight.
(iii) Nose or tail heavy.

### (i) Tendency to Fly One Wing Low

If an aircraft is reported by the pilot to be flying right wing low, it may be due to the following—

(*a*) Incidence on the left wing greater than on the right wing, thus increasing the lift on the left wing.

(*b*) Ailerons warped or out of alignment when the control column is central.

(*c*) Dihedral greater on one side than the other.

(*d*) The wings becoming distorted.

(*e*) Unequal loading.

(*f*) Tail plane out of alignment laterally.

CHECK (*a*)

By placing the aircraft in rigging position and testing the angle of incidence on each wing. Should it be found that the angle of incidence is less than it should be on the right wing, adjust it to the correct setting. If the incidence is more than it should be on the left wing, decrease the same to maker's rigging diagram requirements. It may happen that the wing incidence is correct in which case—

CHECK (*b*)

If the ailerons are not in trim due, say, to stretch or slackness of cable, adjust to standard for type. If warped, aileron should be changed, or droop adjusted to compensate. Take care that this does not cause drag and result in giving the aircraft turning tendency.

CHECK (*c*)

The dihedral angles on each wing should be checked and adjusted if necessary.

CHECK (*d*)

Try with straight-edgc wherever possible in way of spars, and also compare incidence readings on numerous similar places on each plane. Distortion may be due to overtight bracings; if it persists when wires are entirely slacked off, wing must be removed and opened up for investigation.

CHECK (*e*)

This may be due, say, to unequal fuel consumption, or, in a seaplane, to water in a float: the remedy in either example being self-evident.

CHECK (*f*) and, if out of alignment, correct.

A test flight should be carried out when everything has been corrected; should the pilot still report that the aircraft is flying right wing low, give more incidence on the right wing and slightly decrease the incidence on the left wing (both, of course, towards the tips known respectively as "wash-in" and "wash-out.")

### (ii) When an Aircraft Does Not Fly Straight

This may be due to the fin not being in the correct position, which gives the effect of slight rudder. Rubber cord, or a spring in the rudder control system, is sometimes fitted to counteract this defect, and if such or any other device is fitted it must be carefully inspected and treated as part of the flying control system. It must be understood that no alterations beyond the normal adjustment of such a loading device as mentioned can be authorized to correct this error, unless the Ground Engineer is notified through official channels.

An aircraft carrying rudder gives the impression of flying one wing

low. When an aircraft is reported to be flying one wing low and carrying rudder at the same time it is advisable to counteract the turning tendency by adjustments and test flight before giving "wash-in" or "wash-out" to the planes, provided the aircraft was flying in a normal manner previously. Alternatively, holding one wing up will cause drag in that side and cause the aircraft to turn in that direction.

The degree of offset (to counteract torque) of the engine may be incorrect; an engine licensee must be called to correct any such error. In the case of a pusher aircraft having the airscrew close to the fin, the fitting of a new airscrew of different pitch having more or less r.p.m. than the previous one and causing the slipstream swirl to impinge on a different point on the fin may upset the directional stability; such a condition may be counteracted in the manner mentioned above.

### (iii) Nose or Tail Heavy

This defect may be caused through—

(*a*) Incorrect stagger.
(*b*) Incorrect incidence of tail plane.
(*c*) Incorrect incidence of main planes (although both sides may be equal).
(*d*) Incorrect loading of the aircraft.
(*e*) Distortion of fuselage or hull.
(*f*) Water in the hull, main floats, or tail plane. (Seaplanes.)

Place the aircraft in rigging position, check and correct where necessary (*a*) (*b*), (*c*), and (*e*). Regarding fault (*d*) great care must always be taken when loading an aircraft that the C.G. limits are strictly observed.

(*f*) Drain all floats, tail plane and elevators and see that the eyelets in the two latter are clear.

Where fixed servo flaps are fitted to control surfaces, flying errors may often be corrected by "setting" such flaps *away* from the direction of the dip or turn.

CHAPTER II

# 4. TIMBER—DEFECTS AND DETERIORATION

WOOD is not used to a great extent on modern aircraft; there are still, however, numbers of light aircraft of composite construction, i.e. wood, fabric, and metal. Structures made of timber are very much affected by extremes of atmospheric conditions. All timber used in aircraft construction is very carefully selected, therefore the defects dealt with below are those which develop after the aircraft has been in service.

Timbers commonly used are silver spruce, ash, walnut, mahogany, and plywood. Silver spruce is the most widely used for aircraft construction. Ash is used for engine bearers and fuselage struts, tail struts, etc., and walnut for airscrews and packing blocks. Mahogany is used for the construction of hulls, floats, and airscrews. Plywood, usually birch, is used for fairings, sides of box spars, walk-ways, rib webs, covering of the leading edge of wings, tail units, and on flying boats for top surfaces of wings and centre sections.

## Defects

The most serious defects are: (*a*) brittleness, (*b*) compression shakes, (*c*) shrinkage, (*d*) oil soakage, (*e*) water soakage, (*f*) crushing, (*g*) (plywood) sagging, and ply separation.

## Brittleness

Wooden parts become brittle due to the moisture drying out and shrinkage occurring. It is very difficult to detect this serious defect without destroying the part suspected, but if the shrinking is such as to cause slackness of metal fittings it should be reported to the makers or to a Ground Engineer licensed in Category "B" for guidance.

## Compression Shakes

Wooden aircraft structures can absorb vibrations and minor shocks without serious damage, but under large shock loads such as heavy one-wheel, tail, or wing tip landings, compression shakes may be found in the longerons and main wing spars. Only the most careful inspection will reveal the presence of this kind of shake, and an indication is often given by the fracture having caused the varnish to crack across the fibres of the wooden member (see Fig. 12).

## Shrinkage

Shrinkage in timber occurs if the conditions are too dry, resulting in the breaking down of glued joints and slackness of metal fittings. This may obtain particularly on component parts that have been stored for any considerable period.

## Oil Soakage

Engine bearers and other timber parts near to the engines and oil tank must be carefully cleaned, and protective coatings should be maintained to prevent the wood from becoming oil soaked. It may be necessary from

time to time to scrape parts lightly and re-varnish; if the oil has soaked below the surface the strength of affected parts will be impaired.

### Water Soakage

When fitting new struts, etc., great care must be taken that, after shaping, ends are treated with an approved protective coating of varnish or paint, otherwise the timber may become water-soaked and develop blue-stain, a defect to which silver spruce is very subject; this is sometimes on the surface only, but in its more advanced stage it penetrates very deeply and is the first stage of rot.

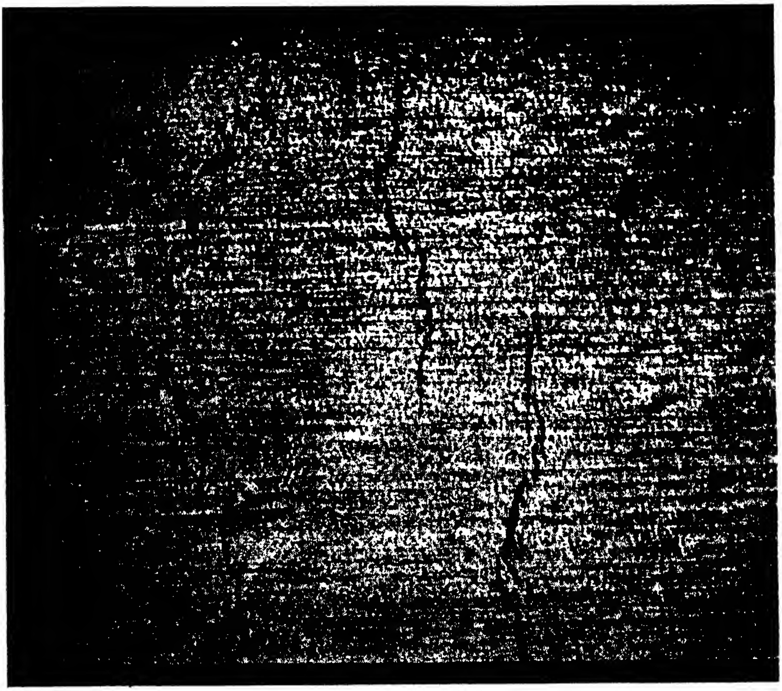

FIG. 12. TIMBER COMPRESSION SHAKE

### Crushing

Wood parts are crushed by the overtightening of metal fittings and incorrect tensioning of bracing wires. The most serious form of crushing is usually caused through bad landings, and this can only be discovered by means of careful and systematic inspection.

### Sagging and Ply Separation

The individual veneers of plywood sometimes become non-adherent. Plywood often sags; the timber itself sometimes loses its moisture and becomes brittle. Plywood parts should always be well protected, particularly around the edges, with liberal coatings of paint, enamel, varnish, marine glue, or other suitable protective material.

## 5. METALS: DEFECTS AND DETERIORATION

All metallic materials used for aeroplane construction are carefully listed and inspected, and also suitably protected against corrosion before the parts are finally passed out from the makers. Most of the subsequent defects and deteriorations can be said to be due to corrosion. In light alloys corrosion is usually in two forms—

(*a*) External.
(*b*) Intercrystalline.

### (*a*) External Corrosion

As very light sections of materials are used in aircraft construction, corrosion will soon weaken the structure, and cause failure. Careful and systematic inspection must be carried out in order to arrest corrosion in its early stages. Fortunately most instances of corrosion are on the surface, and although this kind of corrosion is not very dangerous, being visible by the formation of a white powder (aluminium oxide), it may be liable to form pits and/or cavities. If this pitting is not very deep it can be removed carefully by using a soft scraper and stiff brush; the parts should then be immediately treated with lanoline or protective coatings similar to those used on other parts of the aircraft. If it is found after removing corrosion on fittings that the corrosion is deep enough to cause weakness the fitting must be rejected. In the case of steel plates the bad place may be removed and replaced by a suitable patch.

### (*b*) Intercrystalline Corrosion

Corrosion in this form is extremely dangerous, there being no white powder as in the case of surface corrosion. The only signs are surface

FIG. 13. DURALUMIN—INTERCRYSTALLINE CORROSION

cracks, which are sometimes very small and can only be detected with the most careful examination (see Fig. 13).

These intercrystalline corrosion cracks do not frequently occur, but should be watched for, and however fine or small the crack the part must be immediately rejected. This form of corrosion attacks the crystal boundaries inside the metal, making it weak and brittle. Alclad need not be rejected until about 75 per cent of the aluminium covering (which is about 10 per cent of the total plate thickness) has corroded away, as no pitting of the duralumin is likely until then.

### Mild Steel

There is not much likelihood of cracks developing in this type of material, therefore the chief defect is again surface corrosion. This can

easily be seen because of the rust, which must be removed as early as possible. After cleaning, re-paint. The ground engineer should watch most carefully for corrosion of fittings and tubing at the welds.

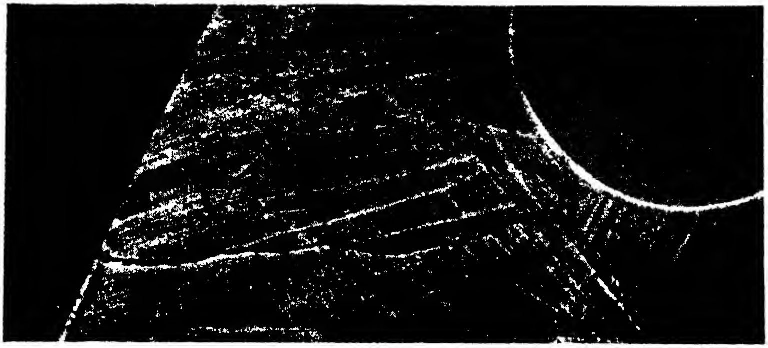

FIG. 14. STAINLESS STEEL—INTERCRYSTALLINE CORROSION

## Stainless Steels

These sometimes show signs of surface corrosion in the form of a reddish stain, but this can easily be removed, and the polished surface restored. Cracks may develop due to intercrystalline corrosion (see Fig. 14).

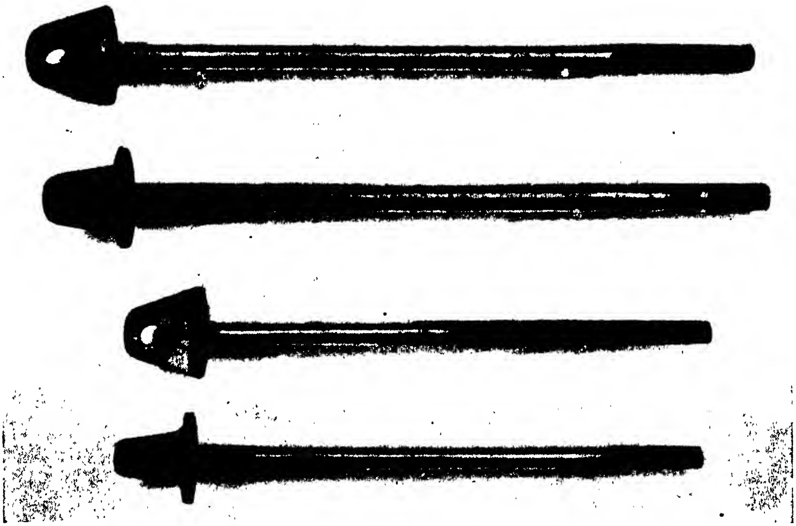

FIG. 15. STAINLESS STEEL—CORROSION

Stainless steels when in contact with wood, particularly in sea-going aircraft, should be frequently examined, as this may cause corrosion as in the case of the bolts shown in Fig. 15.

Of course, defects may be due to a combination of causes, for example, the combined effects of high stress and corrosion are well illustrated by the two photographs, Fig. 16 and Fig. 17. These cracks occurred in service in spars made from high-tensile stainless steel, and it should be noted that although they were primarily caused by corrosion, only very slight external evidence is present. It is unlikely that such cracks will be met with under normal conditions, but a careful examination of all components, from whatever material made, is obviously necessary when it is seen, as here, that such failures can occur.

Fig. 16. Stress and Corrosion Cracks in High-tensile Stainless Steel Spar Flange

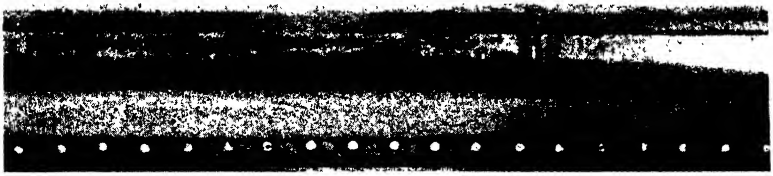

Fig. 17. Stress and Corrosion Cracks in High-tensile Steel Spar Flange

### Special Steels

Axle tubes (nickel chrome) may crack in service due to corrosion. These cracks are very difficult to detect; should there be any doubt the axle should be saturated with paraffin, and the suspected part afterwards dried and coated with whitening. If the axle is cracked the paraffin will percolate through the whitening in the region of the defect.

### Copper Alloys

These are liable to surface corrosion (known as verdigris). Copper pipes may harden and crack or split where the ends have been bell-mouthed. Copper pipes should be annealed periodically at a temperature of from 600° C. to 700° C., and water quenched to re-soften.

### Contact Corrosion

When two dissimilar metals are in contact, e.g. steel and duralumin, galvanic action which accelerates corrosion is set up between the metals. Great care should be taken during examination, as corrosion is very liable to exist, especially underneath fittings.

### Streamline Bracing Wires and Tie Rods

Owing to the fact that bracing wires are very highly stressed in service and are manufactured from special high-tensile steel, great care should be

exercised in their inspection. The most probable causes of failure of these components are—

1. Corrosion.
2. Chafing at intersections.
3. Damage during refitting.

The following points should be carefully noted—

## Corrosion

Before the bracing wires are fitted by the aircraft manufacturers they are coated electrolytically with metallic zinc or cadmium as a protective.

FIG. 18. BRACING WIRE WITH CLIP IN PLACE

FIG. 19. CLIP REMOVED REVEALING BADLY CORRODED AREA BENEATH

This coating is extremely thin (0.0005 in.) and great care should therefore be taken when fitting or adjusting such wires to avoid damaging this coating. On no account should emery cloth or any abrasive be used for cleaning purposes.

Corrosion is likely to appear after considerable periods of service in the form of rust spots which have penetrated the coating. These should be carefully removed by rubbing locally with a brush. The wire should be replaced if the metal is at all pitted underneath the rust. If, however, no pitting is visible the wires may be coated with grease or paint before further service.

The identification clips used on streamline wires are particularly liable to cause corrosion, being made from a metal dissimilar to that used for the wires. It is therefore most important that the clip be moved along the wire and that the portion hidden by it be carefully examined. Figs. 18 and 19 illustrate clearly the necessity for this precaution. If these clips are broken they must not be re-soldered as the necessary heat may impair the temper of the steel. Particulars given on damaged clips should be recorded in the log book, no new clips being fitted.

### Chafing

The points of intersection of cross bracing wires are very important, as it is here that damage may be caused by the two wires rubbing together. Even a very small indentation on a streamline wire is dangerous, as the stress becomes concentrated at this point and may cause fracture.

The "acorns," fibre discs, etc., used at intersections should therefore receive careful attention, and if damaged must be at once replaced. Chafed wires must also be replaced and great care taken in their reassembly. The wires should also be examined for small cracks, particularly if they have had a long period of service or if they have been subjected to heavy vibration.

### Refitting

When refitting or replacing a wire, the condition of the wiring plate holes and the correct alignment of the lugs should be checked. The fork ends and pins of the wire should be examined. When adjusting the length, and in order to avoid damage to the protective coating and the edges of the wire, a special spanner should be used. The lock nuts used must be of brass or cast iron so that if they are overtightened they will not damage the thread of the wire. The correct minimum amount of thread must be in engagement, as indicated by the wire reaching the small hole drilled in the fork end.

### General

Careful watching and systematic inspection are always necessary to check corrosion in the early stages.

All open ended metal tubes must be inspected internally, as, although the external condition may be good, failures can occur due to internal corrosion.

## 6. OTHER MATERIALS

### Fabric Covering

The fabric, sewing thread, and braided cord normally used for coverings and attaching the fabric to the ribs, are of the best quality linen. These materials must be carefully stored and the fabric should be kept in a room of fairly high temperature, 70° F. being suitable. This will ensure the evaporation of all moisture which would prevent satisfactory doping. Prolonged exposure to strong daylight is injurious to fabric.

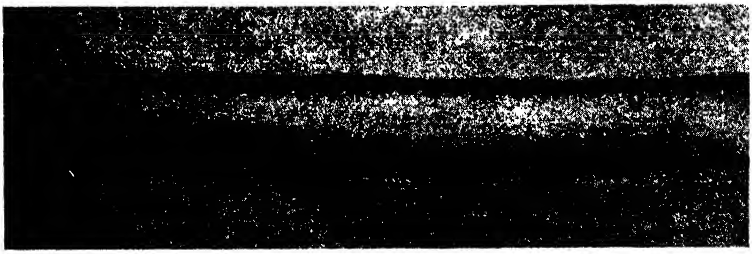

Fig. 20. Fabric Width to Width Seam

### Repair Work

To enable the repairs to fabric coverings to be carried out in a satisfactory manner, it will be necessary for the ground engineer to have a thorough

knowledge of wing covering, sewing operations, and the attachment of fabric to the ribs. These operations are very important, and every effort should be made to restore the damaged coverings as nearly as possible to their original strength and condition. The materials used on the aircraft undergoing repairs must be similar to those already used, and previous methods must be closely followed. The following notes are intended as a general guide. The type of seam used for joining fabric is the double balloon seam, and must be made as indicated in Figs. 20 and 21.

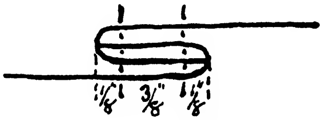


Fig. 21. Cross Section of Seam

The machined seams should have approximately nine stitches per

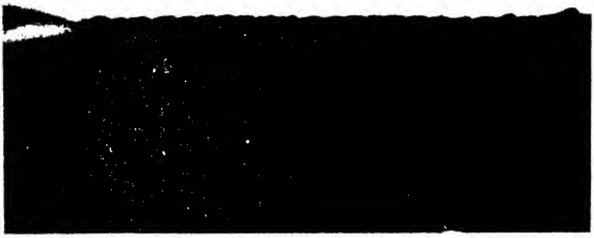

Fig. 22. Fabric Envelope Edge Sewn—Stitches Knotted

inch, using single 40's linen thread. Hand-sewn seams are lock-stitched eight stitches per inch and double-locked every 6 in., using single 18's or double 40's waxed linen thread (see Figs. 22 and 23).

Fig. 23. Fabric Envelope—Edge Sewing and Thread Knotting

The fabric is secured to the component by stringing to the ribs (Egyptian tape between) with braided waxed cord. The pitch of the stitches is 3 in., each stitch being knotted and doubly knotted at every 18 in. (see Figs. 24, 25, 26, and 28).

Special precautions must be taken when attaching the fabric in the region of the airscrew slipstream. For aircraft fitted with engines of 400 h.p. and over, the pitch of the stringing is reduced to 1½ in. (see Fig. 27).

FIG. 24. FABRIC STRUNG (SHOWING KNOTTED SIDE) TO RIB

All stringing of ribs, and sewing threads around the trailing edge and/or end box ribs, must be protected by doping on serrated or frayed-edge tape (Figs. 29, 30, 31, 32, and 33).

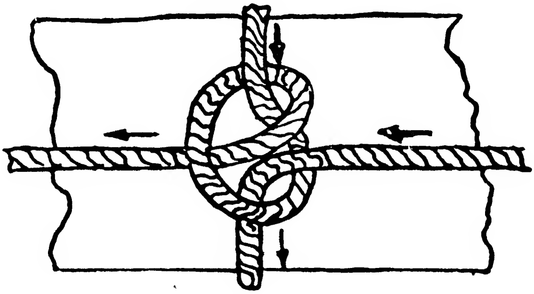

FIG. 25. RIB STRINGING, DETAIL OF KNOT

All repairs should be carried out as detailed above unless otherwise stated in the aircraft maker's approved handbook. If large sections of fabric need replacing, the new fabric, after joining to the remaining

FIG. 26. FABRIC STRUNG (OPEN PITCH) TO RIB

original fabric, should be drawn tight when sewing, and the tension must be uniform over the new area. Care must be taken not to overtighten the fabric on light structures as the additional tightening by doping may cause distortion. When repairing a small tear in the fabric, first remove

the dope around the damaged portion by the use of an approved dope solvent, or by peeling the old dope away, afterwards sewing the edges

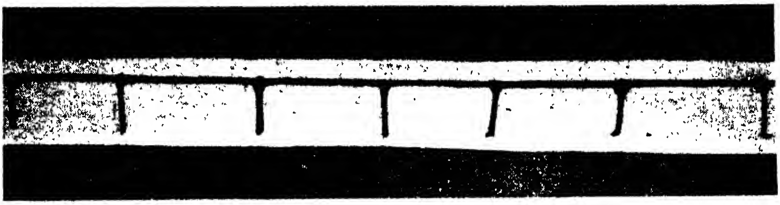

FIG. 27. FABRIC STRUNG (CLOSE 'SLIPSTREAM' PITCH) TO RIB

together and doping on a suitable frayed fabric patch, then covering with the necessary coats of dope as called for under the scheme. Where the fabric

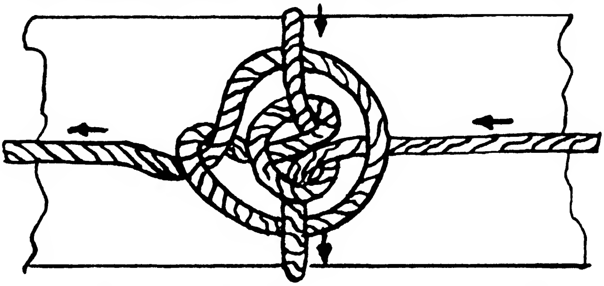

FIG. 28. RIB STRINGING, DETAIL OF DOUBLE KNOT

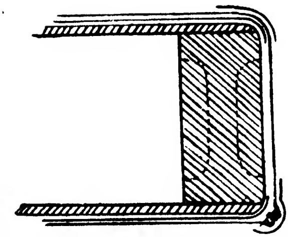

FIG. 29. METHOD OF ATTACHING FABRIC TO REAR SPAR

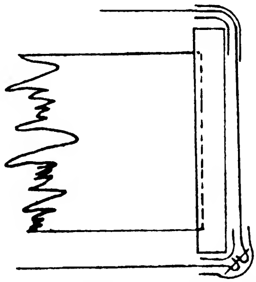

FIG. 30. METHOD OF ATTACHING FABRIC AT END RIB

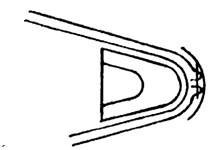

FIG. 31. METHOD OF ATTACHING FABRIC AT LEADING OR TRAILING EDGES

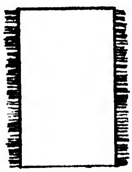

FIG. 32. FRAYED-EDGE TAPE (ALTERNATIVELY, MAY BE SERRATED)

is badly torn the jagged edges should be cut away to a square or oblong shape and a piece of fabric of similar shape inserted, sewn in, and the repair finished as already described. Holes and tears in the coverings must be repaired immediately, as they may rapidly extend by tearing in the wind and the effect may further bring about alteration of the static pressure within the wing, which in turn might increase the normal rib

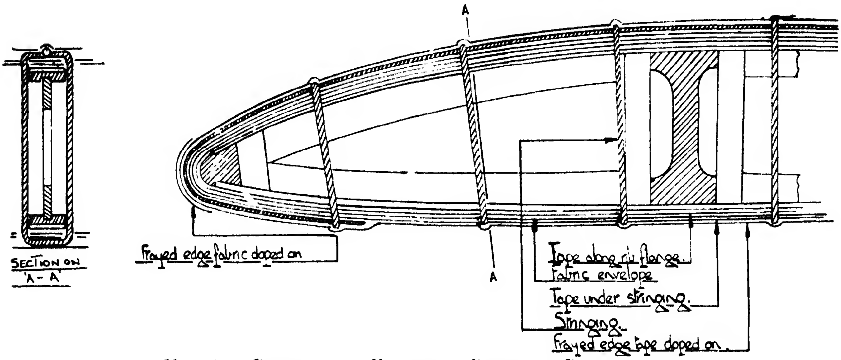


FIG. 33. SECTION OF FINISHED COVERED COMPONENT

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loading. The maintenance of fabric coverings is a very important item both for the safety and efficiency of the aircraft.

## Doping of Fabric

Aircraft dopes are of two kinds: (*a*) acetate dopes; (*b*) nitro dopes. There are several approved proprietary doping schemes, and the makers of these schemes issue instructions for use, which must be followed. The complete doping of fabric-covered components is a method of producing and maintaining a taut, waterproof and airproof surface; it is a protective covering for the fabric. It prevents deterioration of the fabric by light, weather, and service conditions. Pigment is added to dope to protect the fabric from light rays, but as pigments absorb heat a final coat of aluminium is sometimes given in order to reflect the heat rays.

## General Application Conditions

A fairly stiff brush should be employed, of which the bristles must be secured by rivets to avoid loosening by the solvents in the dope. The first coat of dope, which must not be thinned, should be well brushed into the fabric with sufficient pressure to ensure thorough impregnation. Further coats of dope may be brushed or sprayed in accordance with the approved proprietary scheme, which should also be the guide for between-coat intervals, number of coats, etc.

## Atmospheric Conditions (doping scheme for workshops)

Doping should be carried out in a warm dry shop with a temperature of not less than 60° to 70° F., free from draughts, but having efficient ventilation. Moisture in the atmosphere should be kept at a minimum and the relative humidity should not exceed 80 per cent.

## Doping Under Adverse Conditions

Doping schemes for repair or renovation of machines under aerodrome or unheated shop conditions permit doping to be done in the open air.

A sheltered place should be selected where strong draughts and gusts of wind are reduced to a minimum. The weather should be warm and dry; doping should never be done if the temperature drops below 32° F.

### General Precautions

There is a tendency for the pigment to settle out with all coloured dopes, therefore great care must be taken to ensure that the containers are thoroughly stirred and shaken before and during use. It is also very important that dope, dope covering, cleaning solutions or brush wash, etc., of one scheme are not mixed with other schemes.

### Defect and Deterioration

Dope on covered components may, with continuous service, become brittle and crack. This may expose the fabric to weather, which will cause the fabric to perish unless this defect is immediately corrected. The best remedy is to remove the cracked dope film by the use of a dope solvent, thoroughly clean, and re-dope. Another defect known as soggy fabric is due to the deterioration of the dope by long exposure to varying weather conditions; this particularly applies to dope on covered components fitted to marine aircraft which are often moored out for long periods. Soggy fabric may also be caused through neglect to clean off oil, which will in time not only destroy the dope film, but penetrate to such an extent as will result in the fabric perishing, thus rendering components unserviceable. If the dope film only is defective, clean off with dope solvent and re-dope strictly in accordance with the doping scheme on the remainder of the component or components. All fabric components should be kept as clean as possible and even small defects should receive immediate attention; this will preserve the covering and assist in maintaining the performance of the aircraft. The dope film may become chafed, damaged, or punctured locally, and may split or crack; the film should be peeled or dissolved from the area immediately surrounding the damage, and the fabric repaired if necessary, the place then being re-doped as already explained. The sharp places of the component—edges, ends, blocks, rib-peaks, and the walk-ways used by the ground mechanics during their work, etc., as well as all other areas likely to become prematurely worn, should be often and carefully noted and re-coated as required.

## 7. CONTROL MECHANISM: DEFECTS AND DETERIORATION

All hinge pins, and also pins at the control column, should be inspected for excessive wear. Examine the run of cables for fraying, paying special attention to the portions that bear on the fairleads and the attachment of the cables to control surface. Operating levers should be inspected for wear and security, and the splices and eyes for corrosion and stretching All attachment and control rods must be carefully inspected for wear and safety; if any control rods or cables pass through components such rods or cables must be removed and examined for corrosion more frequently on the lower planes and tail units of marine aircraft than would normally be necessary for land aircraft.

It is important that the control stops do not allow movement beyond the limits laid down. The travel of all controls should be checked from time to time, the control column being set in accordance with the maker's control diagram. Careful lubrication is required at all places provided and at all hinge pins and other moving parts, which must be cleaned from time to time for examination. All chains complete with attachments must

be checked for stretching, and for wear and corrosion. Throughout the whole control system it is most important to inspect the split pins for wear and corrosion; the pins must be replaced if affected. All split pins must be of correct size and length and must have a washer between them and the fitting. Having once been taken out of a fitting they must on no account be used a second time.

When replacing cables or other parts of a control unit the whole system must be examined for correct functioning and travel of control surfaces and travel attachments, for freedom and travel throughout the control range, and for locking of all attachments. After any replacements or adjustment of flying controls the examination must be duplicated.

### Examination of Slack in Aircraft Controls

Undue slackness in the control system of an aircraft is liable to cause flutter; it is important, therefore, that special attention be paid to the fit of all control bearings, which should be as free from play as possible, consistent with ease of manipulation of the controls. Any slackness at these points will be magnified by the length of the control column, levers, etc.

Control cables which pass through or over fibre fairleads are to be left dry and not greased, as the grease picks up grit and abrasive matter which accelerates the wear of the cable.

## 8. INSPECTION AFTER A BAD LANDING

### Land Aircraft

1. Jack up under fuselage until wheels are clear of the ground.
2. Remove landing wheels and examine hubs and brakes.
3. Check undercarriage struts for straightness. Renew if bowed or damaged, and inspect all points of attachment, bolts and pins for partial shear and holes for elongation.
4. Disconnect oleo legs at lower end and check axle for alignment.
5. Remove tail wheel or skid assembly, examine for distortion and excessive play, and inspect the structure at the points of attachment and along those members of the frame through which load is distributed.
6. Set fuselage in flying position, and check all rigging dimensions.
7. Remove all inspection covers, and check internal bracing wires; if these are very slack carry out further inspection of internal fittings, spars and attachment points. Never adjust bracing wires unless the cause of slackness has been discovered.
8. Unlace fuselage bag and examine internal structure for damage to longerons, struts, fairings, and bracing wires.
9. Inspect all controls. If the aircraft is fitted with folding wings these should be tested for correct functioning, and an examination made of attachments and locking arrangements.
10. Should the wing tip come heavily in contact with the ground, or any other object, examine the points where interplane struts are attached to the wings. Carefully inspect the rear spar and aileron attachments, also the wing root fittings. If the wing fabric is puckered the component affected must be opened up and checked internally, also the spars carefully inspected for fractures, i.e. splitting, crushing, and compression shakes. It is most important that a systematic inspection be carried out after a bad landing, and to emphasize the importance of this fact it must be remembered that the load on the bottom plane spars may have been transferred by the struts and bracing wires to the upper plane spars, and

by virtue of the lift wires may have given compressive stresses to those members. These stresses can again have been reduced or increased by the tension in the front, and compression on the rear spars, caused by the drag component of the force applied by meeting the ground or other obstacle. It should be realized that damage may occur in a region remote from the point of contact, especially in the locality of the wing cellule attachments and also the anchorages of points carrying concentrated loads, e.g. petrol tanks and engine mountings.

### Flying Boats

Heavy drift landing may damage the wing tip floats, in which case careful inspection of the float struts and bracing wires should be carried out. The attachment fittings of the wing tip floats to the main planes should be removed so that the spars can be inspected for crushing, splitting, or compression shakes. Should there be no definite failure of the spars in this respect, check internal wing bracing wires for correct tension, and examine fittings and main wing bracing wires at points immediately above float attachment fittings, also the interplane struts and their fittings.

HEAVY TAIL LANDINGS on flying boats invariably damage the leading-edge ribs and fabric of the tail plane.

Carefully inspect the whole tail unit and test rudder and elevator control cables for signs of stretching, and the operating levers and rods for distortion and freedom of movement. Check the tail adjusting gear for functioning and the tail plane struts for bowing. The front spar of the elevator along the line of the hinge pin fittings should also be examined for failure. A very heavy "pancake" landing on the hull may result in buckling of the planing bottom and sides of the hull, and damage may occur to the frames and steps. Carefully inspect for failure of material and check wing attachment fittings on the hull, on upper and lower planes, and upper side of wing root fittings to centre section.

Carry out further inspection as for land aircraft.

## 9. WHEEL BRAKES

Owing to rapid advances in technique various versions of the Bendix brake (some of which are here described) may be found on aircraft now in service. Maintenance instructions for the particular type of brake fitted will be found in the handbook issued by the makers of the airframe concerned.

### 1. Bendix Mechanical Cable-operated Brakes

The brake itself (Fig. 34) is of the two-shoe servo type, so constructed that the rotation of the wheels contributes considerably towards the braking power. The operating lever incorporates a cam block, which bears against the toe of the primary shoe. As the brake is applied, this cam block forces the primary shoe into contact with the drum. The friction between the drum and the primary shoe forces the latter against the secondary shoe, to which it is connected by an adjustable link, forcing it against the drum. The farther end of the secondary shoe is anchored to the backing plate which takes the torque.

DIFFERENTIAL CONTROL

The principle is hand lever operation of the brakes, in conjunction with a steering system connecting with the rudder bar. In some systems the necessary levers, pulleys, etc.. are attached to various points on the

aircraft, but a later development is the Bendix Differential Control Unit (Fig. 35) described below.

Between the top and bottom plates *A* swings the main lever *B* which carries two pulleys round which pass the brake operating cables, the ends of which are coupled to the false rudder-bar *C*. The false rudder-bar is connected to the rudder bar in the cockpit, either by two cables or by a

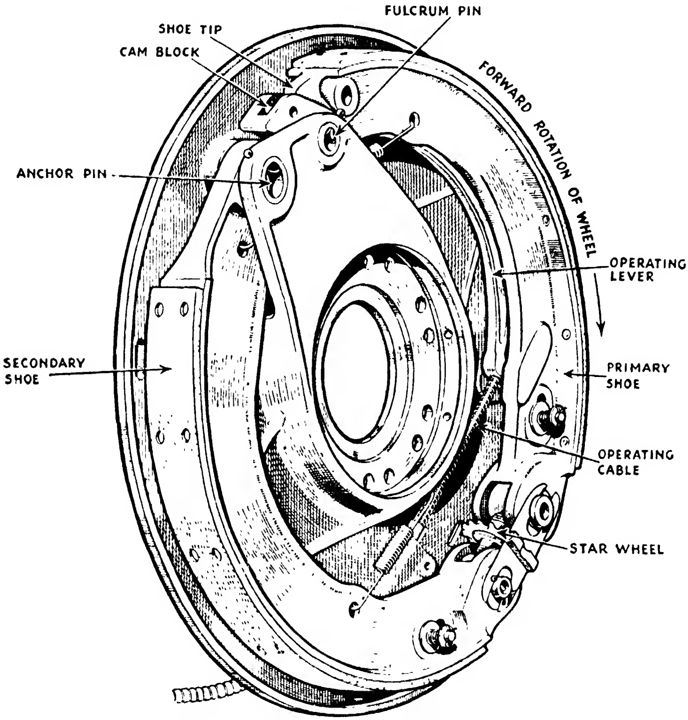



Fig. 34. Bendix Aircraft Brake

single rod. The main lever *B* is connected to the handbrake lever. In order to steer the machine by the brakes, the pilot first applies them approximately one-third of the maximum amount, and then steers the machine by using the ordinary flight rudder-bar movements. For full brake or parking on the aerodrome, the hand lever is, of course, applied to its maximum extent.

## 2. Maintenance of Bendix Mechanical Cable-operated Brakes

1. *Running Adjustments.* (1) Jack up machine with wheels off the ground.

(2) Ensuring that operating gear moves freely, and that brake operating lever in the cockpit is in the "off" position, expand shoes by means of star wheel which controls the adjustable link, until it will no longer turn.

(3) Slacken back star wheels until landing wheels are just free.

2. *Check for Free Wheels at Full Rudder.* (1) Put rudder hard over

to starboard, and make sure that starboard wheel is free. If not, slack back star wheel until wheel is free, or only a slight drag is felt.

(2) Repeat for port rudder and port wheel. (If the brake operating gear is correctly adjusted, full differential braking will be obtained by applying the brake lever two or three notches, and operating the rudder to port or starboard. Maximum braking, sufficient to hold the machine

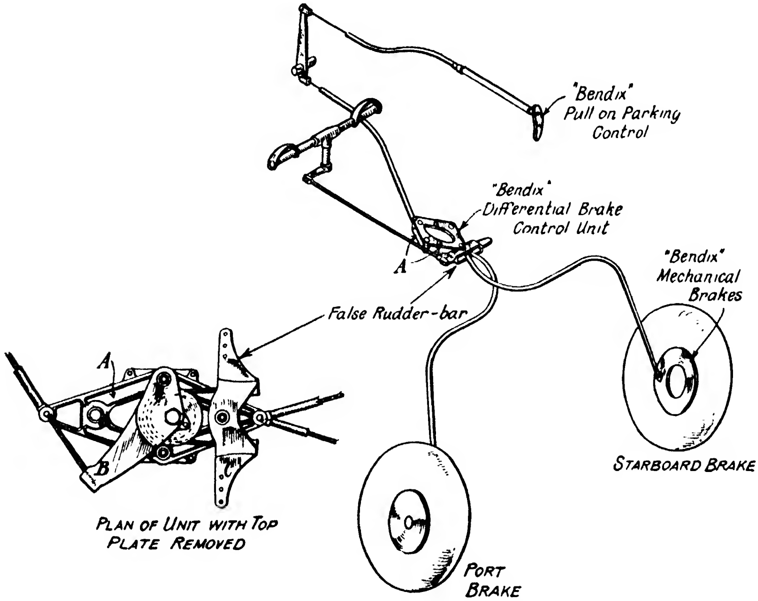



FIG. 35. BENDIX DIFFERENTIAL CONTROL UNIT

against the engine(s) should also be possible before lever has reached end of travel.)

NOTES

Section 2 only applies to machines fitted with differential braking systems.

A tendency to pull to one side or the other does not necessarily indicate incorrect adjustment, but may indicate the presence of oil or water on the brake linings, which should be attended to immediately. While water will dry off, it is not possible successfully to eradicate oil or grease from linings, and in such cases the brake shoes should be replaced.

Do *not* attempt to reline the brake shoes. Replacement shoes, complete with linings cemented and riveted on, and accurately ground to a true radius, should be obtained and fitted in place of the old ones.

3. *Brake Overhaul.* This would normally be carried out whenever the machine is overhauled under "C. of A." Regulations, or whenever brake linings are sufficiently worn to need renewal.

(1) Jack up machine and remove wheels.

(2) Check axle fittings, brake fixing bolts, and any other points where wear is likely to occur.

(3) Remove brake springs, taking care not to overstrain the large shoe retracting spring. It is advisable to renew the shoe hold-down springs. Take care not to lose the D-washers on these springs.

(4) The shoe ring having been removed, dismantle star wheel and pivot nuts and re-assemble these to the new shoes. A very slight amount of Bendix Back Plate Grease should be smeared on the pivot nut threads and on the lever fulcrum pin. The *left-hand* pivot nut, which is identified by a circumferential groove, is *always* assembled to the shoe at the operator's *left hand*, when the brake is held shoes uppermost with the star wheel nearest to the operator's body.

(5) Re-assemble shoe ring to brake, replacing springs in reverse order to their removal.

(6) Slacken off the lock nuts on the cable adjusters at each brake and at the hand lever quadrant, and screw in the adjusters as far as they will go.

(7) Examine brake drums for condition of rubbing surface. The drums should be thoroughly cleaned out with petrol, so that any traces of grease are removed. Where an excessive quantity of grease is present, steps should be taken to prevent this recurring.

(8) Replace brake in wheel and remount wheel and axle.

(9) Expand shoes into drum by means of star wheel.

(10) With rudder bar in "straight ahead" position, and hand lever in "off" position, screw out cable adjusters at each brake until no slack can be felt between the casing ferrule and the abutment. Then tighten up the lock nuts.

(11) Repeat this procedure, with the cable connections on the hand lever, and the differential unit, until all free movement is taken out of the hand lever.

(12) Slack off the brakes and adjust as in "Running Adjustments."

THE CONTROL CABLES

1. Periodic inspection of the brake-operating cables should be made, and where such inspection shows that the outer casing is cracked or worn they should be replaced. This is most likely to occur at points where a good deal of flexing takes place, e.g. between the fixed and sliding parts of the undercarriage leg, etc.

2. Complete replacement cables are available for all types of machines to which Bendix Aircraft Brakes are fitted and should be used in every case where replacement is necessary.

DO NOT REPAIR AN EXISTING CABLE; REPAIRS ALTER CABLE LENGTHS AND CAN HAVE SERIOUS CONSEQUENCES.

### 3. Bendix Fluid-operated Brakes (Pneumatic)

This brake (Fig. 36) is also of the two-shoe servo type, but the construction permits a servo action in the reverse direction also, against the necessity of parking an aircraft up a slope, or other contingency involving the need for checking backward movement.

Fig. 37 shows the operating mechanism, which is suitable for either air or liquid operation. It consists essentially of a piston *A* in the cylinder *B*, which is bolted to the backing plate *C*. Piston rod *D* connected to the piston houses two hardened steel balls *EE*, which are free to slide transversely in the piston rod. These are in contact with the tappets *Gp*, *Gs*, which, through the rods *Hp*, *Hs* and fulcrum pins *Jp*, *Js* operate the primary and secondary shoes.

When the brake is applied, the operating fluid (air or liquid) forces the

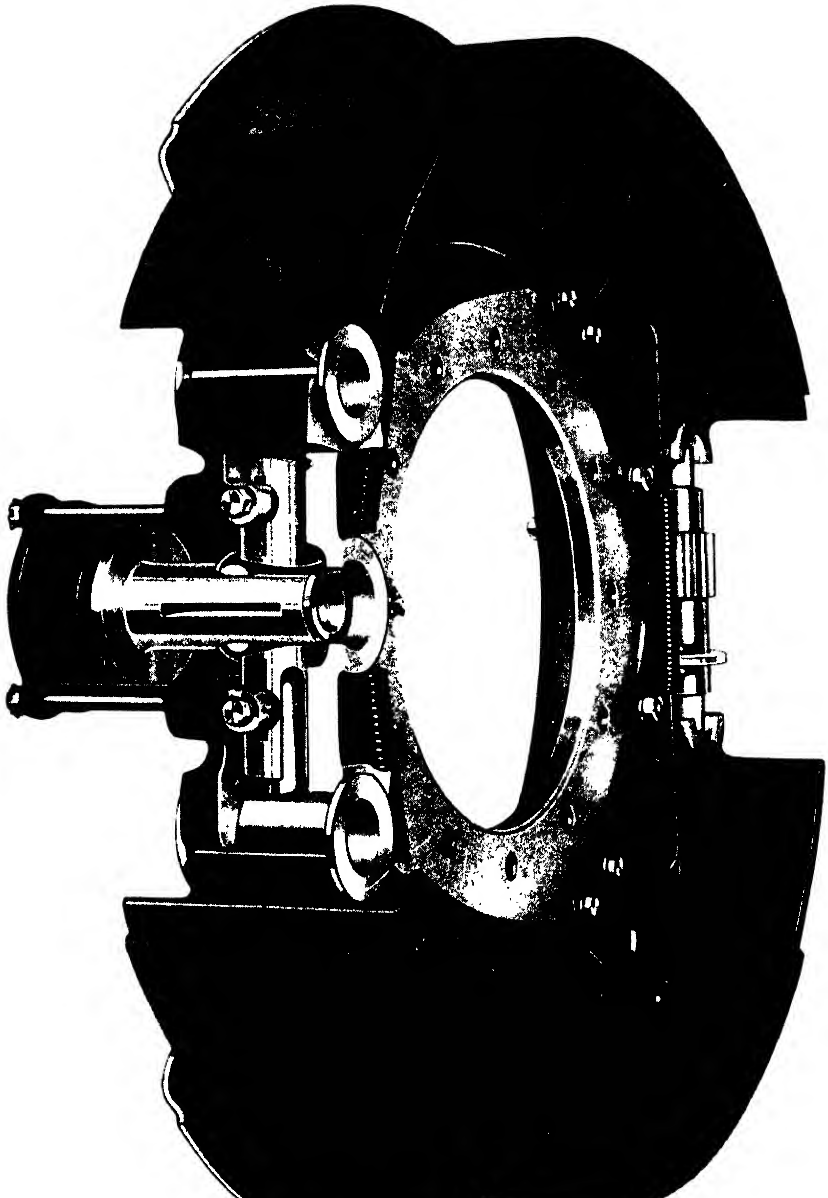


FIG. 36. BENDIX AIRCRAFT BRAKE WITH PORTIONS OF THE TORQUE PLATE CUT AWAY TO SHOW THE OPERATING MECHANISM

piston up the cylinder. The balls are thereby pushed against the inclined faces of the tappets. Tappet *Gs* is held in place by a spring, but tappet *Gp* is forced outwards and pushes fulcrum pin *Jp* off its seat and so forces the primary shoe against the drum, starting the sequence of operations described previously. The brake shoes are maintained in, and returned to, their central "off" position by a pre-loaded centralizing spring. This may be set in position by a bolt which passes through a slot in an extension of the back plate.

## 4. Maintenance of Fluid-operated Brakes

The brake shoes are connected by an adjustable link consisting of a toothed pinion with extended bosses carrying right-hand and left-hand threaded adjusting screws, the other ends of which are located in pivots

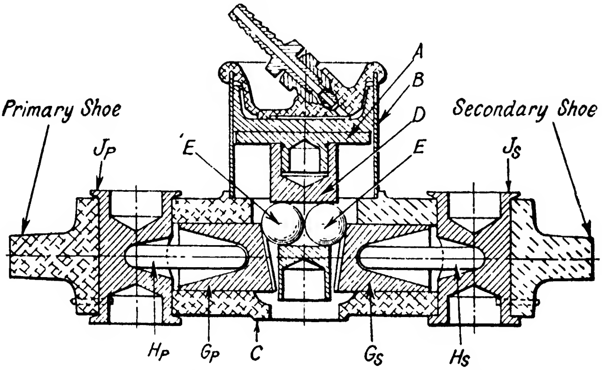



FIG. 37. CROSS SECTION BRAKE ADJUSTMENT

in the shoe ends. A crown wheel meshes with the pinion and the crown wheel spindle projects through the dust shield and is provided with a squared end for a spanner.

1. To adjust the brake, turn the adjuster spindle *clockwise* to *expand* the shoes until no movement is possible.

2. Then turn backwards, i.e. in anti-clockwise direction, six notches or "clicks." This will free the wheels and provide the correct shoe clearances.

NOTE. It is advisable also to centralize the shoes (without jacking up) every 100 flying hours.

### MAJOR ADJUSTMENT OF BRAKES

This is only required for the initial setting, upon installation of brakes, or when chassis has been dismantled for "C. of A." purposes, or when new brake shoes are fitted.

1. Jack up machine so that wheels are clear of the ground.

2. Taking *one brake at a time in each wheel* slacken off the centralizer nut, expand shoes by means of adjuster until the wheel cannot be turned by hand.

3. Make sure that the centralizer has settled into position by tapping the nut slightly. Then tighten the centralizer nut. Slack off six "clicks" of the adjuster. The clearance between linings and brake drum should then be between 0·010 in. and 0·015 in.

## 5. The Differential Control Unit (Pneumatic)

The control unit (Fig. 38) contains two relay valves *AA*, one for each brake, arranged diagonally on parallel axes and operated by the pressure of cams *Cs* (for starboard brake) and *Cp* (for port brake), on the plungers *Bs*, *Bp*. The cams are carried on, and rotatable about, a shaft *H*, mounted on the internal control lever *E*, which is operated by a cable connected to

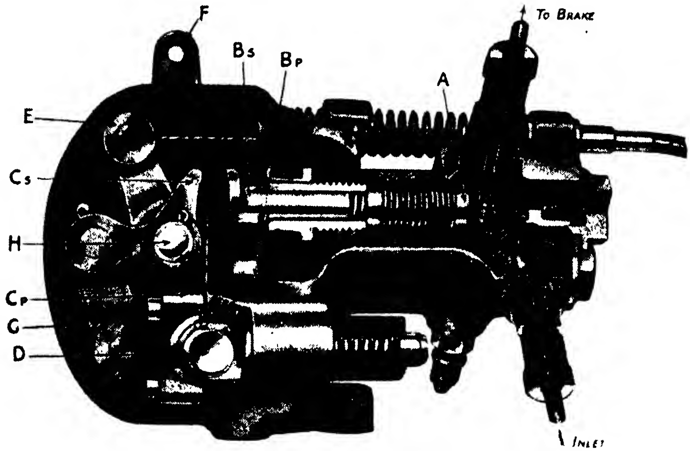



FIG. 38. DIFFERENTIAL CONTROL UNIT

a trigger on the flight control column. The cams operate simultaneously through the movement of the lever *E*, about the axis of shaft *D*, and differentially by a rotary movement about shaft *H* imparted to them through the parallel linkage *G* by the external steering lever *F*, which is connected by a rod to the flight rudder-bar.

In flight the cams are clear of the plungers so that steering movements do not operate the valves. For ground steering they are brought close to the plungers by the lever *E* and open the starboard or port valves by the clockwise or anti-clockwise rotation imparted to them by the steering lever *F*.

To pull up or park, the internal lever is moved farther forward, carrying both cams, which push both valves open, thus operating both brakes simultaneously.

## 6. The Relay Valve

*How it Operates.* When the plunger *B* is pushed it closes the exhaust port at *C*, as shown in Fig. 39 (2). Further movement of the plunger compresses the spring *D*, and lifts the valve *E* off its seat *F*, see Fig. 39 (3). Compressed air at tank pressure can then enter the braking system through the annular space *C*, until the pressure of the air in *G* equals the spring pressure, when the valve automatically closes and attains the position shown in Fig. 39 (2).

Further movement of *B* repeats the sequence of operations and

increases the pressure in the brake. If *B* is released the spring pressure is reduced, and the valve then exhausts until the air pressure in *G* balances the spring pressure. If *B* is fully released, the brake system will be entirely exhausted and the valve will take up the position shown in Fig. 39 (1) with the inlet valve closed and the exhaust valve open. From the illustration, it will be seen that complete air seals are ensured by the resilient valve

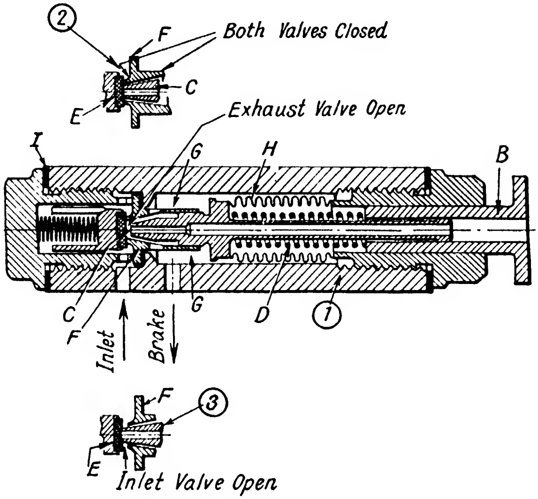


FIG. 39. RELAY VALVES

seat at *E*, the convolvic piston *H* and the cap seal *I*. The ease with which the valve *E* can be changed is also apparent.

## 7. Installation

A complete brake installation is illustrated in Fig. 40. The differential unit may be mounted in any position and the method of connecting the steering lever to the rudder-bar or pedals arranged to suit the machine in which it is installed.

The diagram shows a slip link on the unit end of the rudder connecting rod. This may be fitted in cases where it is desired to have a few degrees of free rudder movement without operating the brakes. A centralizing device on the differential unit ensures that both brakes are off, and that there are no air losses during this free movement. The operating control shown is the special Bendix design mounted on the control column and operates the unit by cable and conduit.

### GENERAL MAINTENANCE

*The Air Piping System.* If the centre indicator of the triple pressure gauge registers a drop in pressure, check for leaks as follows—

(*a*) With a small brush smear a soap-and-water solution over each pipe joint. The formation of a bubble indicates a leak.

(*b*) Break the leaking joint and inspect the flared end of the pipe. If it is cracked or pulled too far through the collar, cut flared end off, re-flare pipe, re-make joint and test again.

(*c*) Check also the inflating valve. This is a Schrader valve and easily renewable if necessary.

*Air Filters.* Inspect these every "C. of A." and renew the felt inserts.

*The Differential Unit.* If, after checking all pipe joints and connections, and also the inlet and outlet connection on the differential unit, a drop in pressure is still noted, remove the differential unit for inspection.

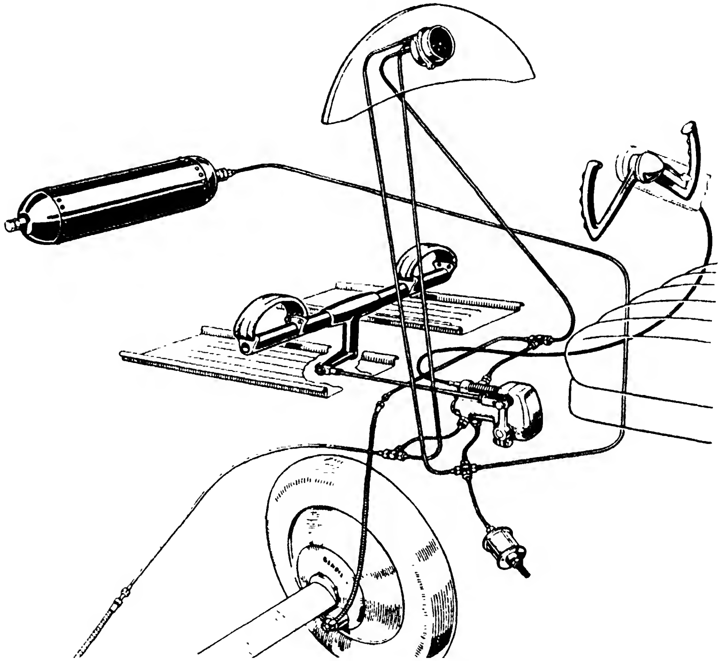


FIG. 40. BENDIX BRAKE INSTALLATION

(*a*) Unscrew the two hexagon caps at the end of the body (Fig. 38) and take out the slotted plugs, which will be found to contain the valves. These are small cylinders with a hard synthetic insert at the closed end.

(*b*) Clean surface of insert completely. If any dirt or other foreign matter is present, this is probably the cause of the leak.

(*c*) Beyond the valve is the valve seat and its gasket. Remove and inspect. If gasket shows deterioration, renew it.

(*d*) If this procedure does not cure the pressure drop, replace the unit with a spare one and return to makers for overhaul.

*Control Lever and Cable.* (*a*) With the control lever in the "parked" position and held by the parking catch, the triple pressure gauge should register identical pressures on each of the brake dials within 5 lb. per sq. in. and up to a maximum of 80 lb. The valve tappets in the differential unit should at the same time be hard up against their housings.

(*b*) The cable can be adjusted to give these conditions by means of the screwed abutment located behind the control wheel spindle. It should be specially inspected for wear at these points—

1. The connection to the control lever.

2. The connection to the internal lever of the differential unit.
3. Round the pulley at the rear of the control column.

## 8. The Bendix Hydraulic Brake System with Two Leading Shoe Brake

The Bendix Hydraulic Brake system (see Fig. 41) consists of four components.

(*a*) A reducing valve to step down the main feed pressure to the lower pressure required for the brakes.

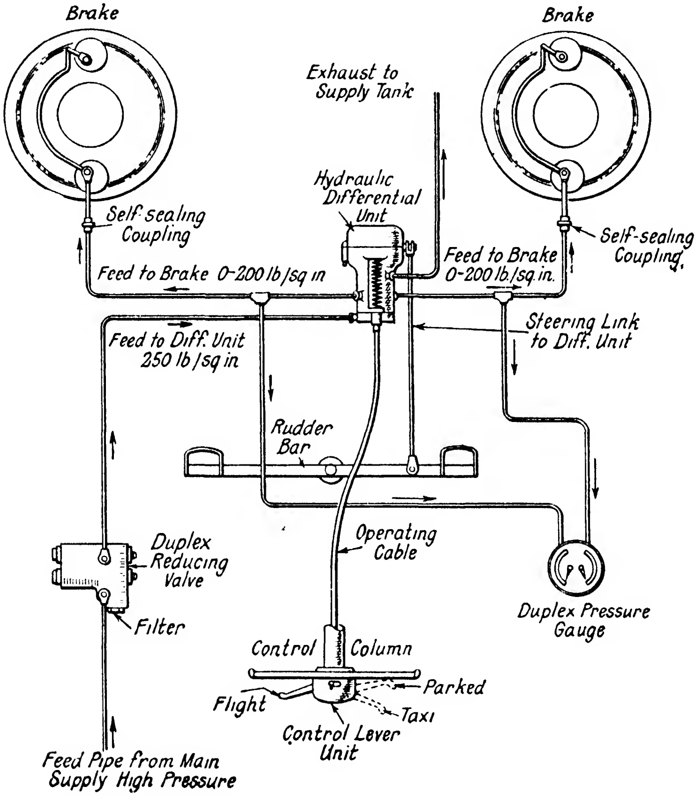



FIG. 41. BENDIX HYDRAULIC BRAKE SYSTEM

(*b*) A differential control unit which admits pressure to the brakes progressively, either simultaneously, or alternatively to each brake for ground steering purposes.

(*c*) A control lever mounted on the pilot's control column.

(*d*) A Duplex pressure gauge registering separately the pressure applied to each brake.

(*a*) THE REDUCING VALVE (see Fig. 42)

This is of Duplex construction with primary and secondary valves and a filter on the input side to prevent solid matter from entering the brake

system. Normally the primary valve is held off its seat by a compression spring housed beneath a hydraulic piston. When the working pressure is exceeded the spring collapses, the piston moves downwards, drawing the valve on to its seat and cutting off the fluid. The secondary valve chamber is connected to the primary but the spring is set to collapse at a higher fluid pressure. Thus, should the primary valve fail to function and the pressure on the brake or output side build up, the secondary valve spring will collapse before an excessive pressure is reached and shut off the fluid.

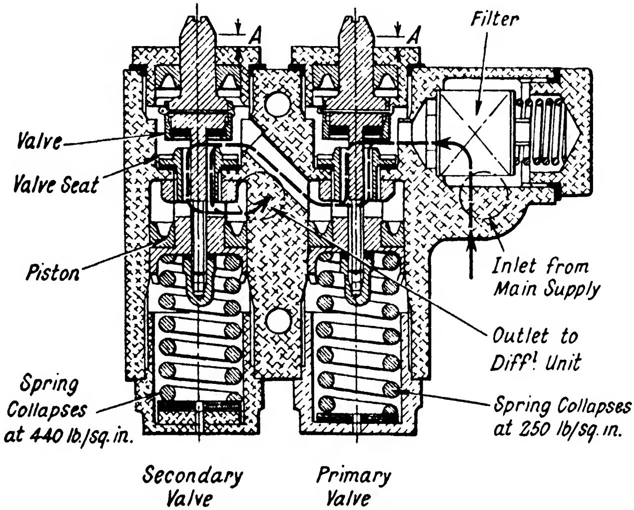



Fig. 42. When Parallel Portion of Primary Valve Spindle Disappears Valve is Closed. If this Happens to Secondary Valve Spindle it Indicates that Primary Valve Needs Attention

Indicators protruding through the valve cups show whether the primary or secondary valves are in operation.

(*b*) The Bendix Differential Control Unit

This control unit gives differential braking, the brakes being applied and progressively controlled by a thumb lever on the pilot's control column, the proportion of port and starboard braking being controlled by rudder-bar movement.

It consists of the hydraulic relay valves, one for each brake, and the parallel cam linkage for controlling them.

*The Relay Valves.* Each relay valve (see Fig. 43) is housed in a cylindrical barrel on the main casting. At the inner end a tappet, operated by the cam mechanism, slides in a gland against a compression spring contained in a flexible metallic bellows in the end of which is a tubular exhaust valve.

At the outer end of the barrel a banjo connection houses the inlet valve—a steel disc held in place by a plunger and spring. This valve seats on the exhaust valve housing containing the exhaust valve disc and push rod arranged so that the inlet valve is opened immediately after the exhaust nozzle seats in the exhaust valve disc.

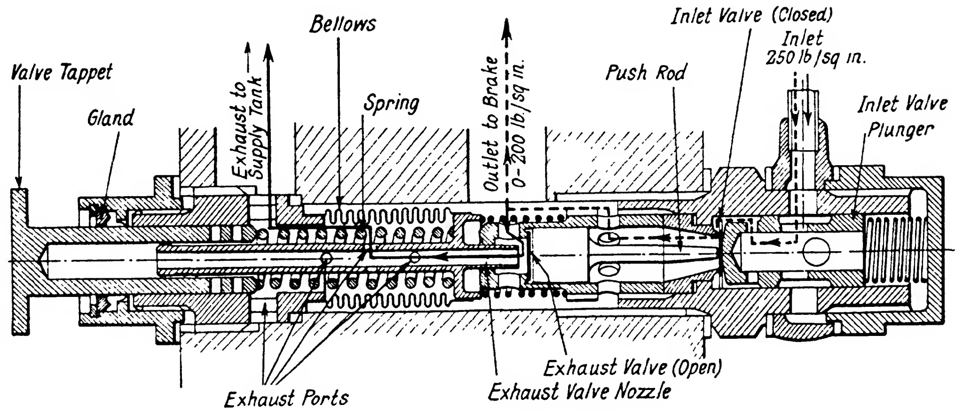



Fig. 43. Bendix Relay Valves

At the inner end the bellows body is held by a gland. There are exhaust ports in the bellows body and the gland itself is bored to accommodate the valve tappet. The valve tappet is bored to form a guide for the central exhaust nozzle.

When the tappet is operated by the cam mechanism it transmits the operating pressure through the compression spring to the tubular exhaust valve, forcing it against the disc and the plunger, thereby closing the exhaust valve. By further movement, the inlet valve push rod forces the inlet valve disc off its seat, admitting fluid under pressure to the barrel round the collapsible bellows and out of the ports in the barrel to the pipe line leading to the brake. When the pressure outside the bellows is greater than the spring pressure inside, the bellows collapses slightly, allowing the inlet valve to reseat itself and maintain that pressure on the brake. Further pressure on the valve tappet will open the valve again and raise the braking pressure progressively.

When the brakes are to be released the valve tappet is released, the bellows collapses until the exhaust valve withdraws from its seat, when the fluid is released to flow down the exhaust tube, through the cross drilled holes to the interior of the bellows and from thence through the exhaust ports to a pipe back to the fluid supply tank. At the same time the inlet valve compression spring brings the inlet valve disc back on to its seat and shuts off the main supply again.

The operating mechanism for the relay valve is exactly the same as for the pneumatic differential control unit already described on page 27.

(*c*) THE CONTROL LEVER

This is exactly the same as for the pneumatic system already described on pages 27 and 30.

**The Bendix Two Leading Shoe Hydraulic Brake** (see Figs. 44 and 45)

The Bendix Aircraft Brake has two shoes, both of which are leading shoes. Each has its own source of operating power and its own adjustment. At the operating end is a hydraulic cylinder, the piston of which has a plunger extension carrying two rollers in a transverse bore.

Movement of the piston under fluid pressure forces the rollers down the face of shoe tappets which move outwards and expand the shoes into the drum. One of these tappets is adjustable and has a tapped and toothed sleeve containing a screw with slotted head which engages the shoe input end. The other tappet has a head with a radially inclined face, forming an angular abutment for the anchorage end of the other shoe which is provided with a sliding pivot. The braking load is taken by this tappet and transferred to the housing on the torque plate. It will be seen then that this tappet remains stationary during braking, as an anchor for one shoe, while the adjustable tappet is forced out by the plunger rollers and operates the other shoe. A similar action takes place in the other operating mechanism at the opposite ends of the shoes. The "floating wedge" principle permits equally good braking in reverse drum rotation, the tappets exchanging functions, the input ends of the shoes becoming anchorage ends and vice versa.

Adjustment for lining wear is provided at each shoe by means of a toothed crown wheel engaging the toothed tappet sleeve and provided with a square ended shank protruding through the dust cover.

RUNNING ADJUSTMENTS

(*a*) *Brakes* (adjustment for lining wear). (1) Tighten up *both* adjusters

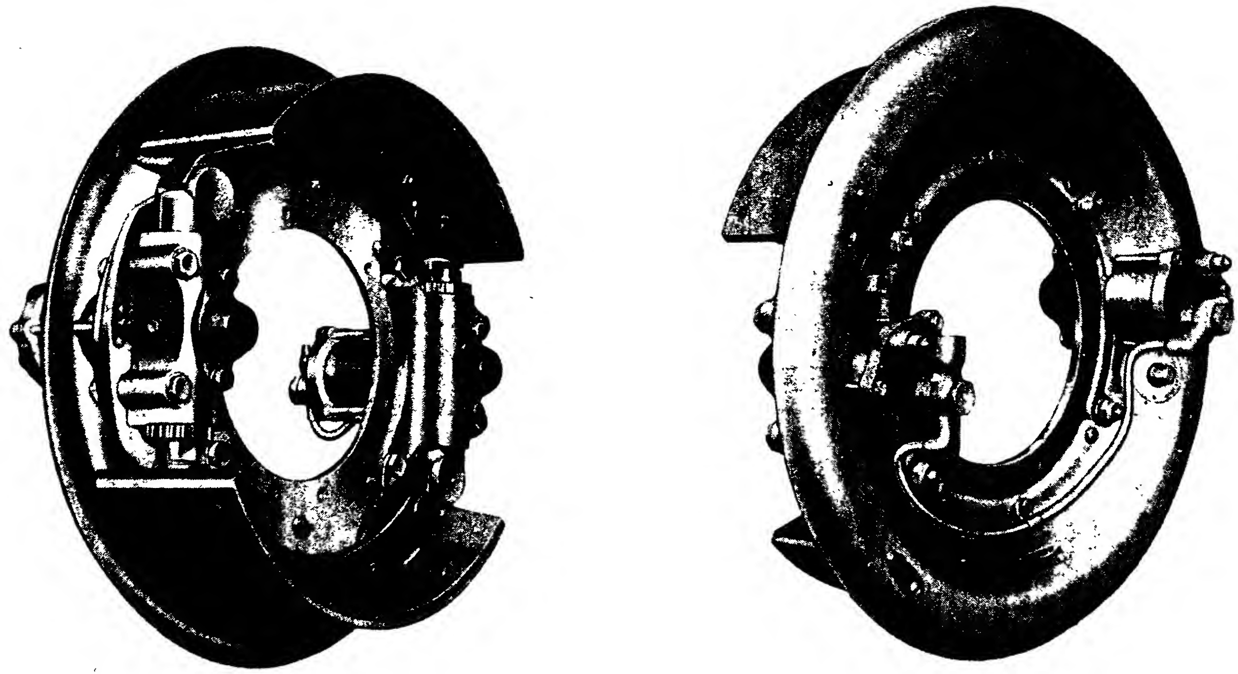


Fig. 44. Bendix Two Leading Shoe Hydraulic Brake

(there is one for each shoe) by turning in a clockwise direction until the shoes are stopped by the drum.

(2) Slacken off by turning adjusters back a quarter of a turn. This gives the correct lining-to-drum clearance.

(*b*) *Operating Cable* (control lever to differential control unit). (1) With rudder-bar set in the straight ahead position, check to see that Duplex Pressure Gauge shows zero and maximum pressure with control lever in "taxi" and "brake full on" positions respectively.

(2) There is an adjuster on the cable. Screw this out in small stages to make gauge register maximum pressure, observing whether the needle returns to zero when control lever returns to "taxi" position. If this does not return from maximum to zero, screw the adjuster back inwards again.

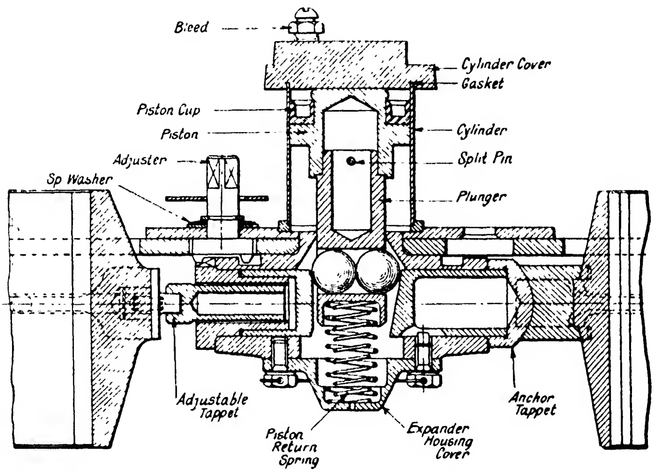



FIG. 45. CROSS SECTION OF FIG. 44

(*c*) *Check for Differential Braking.* With the control lever in "taxi" position the brakes should be off but rudder movement should show pressure on the corresponding brake. Each brake should get the same pressure for the same angular movement of the rudder.

(NOTE. Maximum rudder movement should register not less than 150 lb. sq. in. on the gauge.)

If one gauge shows less than the other at full rudder, correct by shortening or lengthening the connecting link between rudder bar and differential unit.

## MAJOR OVERHAUL

(*a*) *Brakes.* (1) Jack up machine, remove wheels, and withdraw brakes.

(2) Inspect linings for wear and the presence of oil or grease.

(3) If linings are worn down close to rivets, relining is necessary. *Do not attempt to reline shoes but use Bendix completely lined and ground replacement shoes supplied by the makers.*

(4) If oil is present on the linings, renew the shoes also. Washing with petrol is no use as the linings are impregnated with oil which comes up to the surface again with the heat of braking.

(5) Thoroughly clean brake drum with petrol to remove all traces of oil or grease.

(6) Replace brakes and wheels.

(7) Re-adjust brakes as in "Running Adjustments."

(b) *Differential Control Unit and Reducing Valve.* Servicing these units is a bench job involving the use of a pressure-test rig. Therefore, if either shows any defect, replace it with a spare one and return the defective unit to the makers for re-conditioning.

**The Avery Wheel and Brake**

The Avery brake is of the disc type, and there is no self-energizing or servo action, the torque exerted by the brake being in direct proportion to the pressure applied to the capsule. The brake may be applied pneumatically or hydraulically through the nozzle which is carried by the outer hub flange. It is suitable for operation by any known types of control units.

As will be seen from the sectional drawing, Fig. 46, the wheel is made as a casting, which is of magnesium alloy. The hub centre is protected by an axle sleeve *H*, through which the axle is passed and to which it is clamped rigidly. The sleeve, with the outer hub flange and brake diaphragm *D*, is held against any tendency to rotate by means of the dowel holes *J* which engage with dowels attached to the axle flange. The outer brake casing *C* is attached to the wheel casting by the screws *B* and rotates with the wheel, a dust seal being made with the outer hub flange. Friction surfaces attached to the diaphragms *D* are sandwiched between the two braking surfaces of the wheel which are lined with hard detachable metallic facings. The normal clearance is approximately half a millimetre.

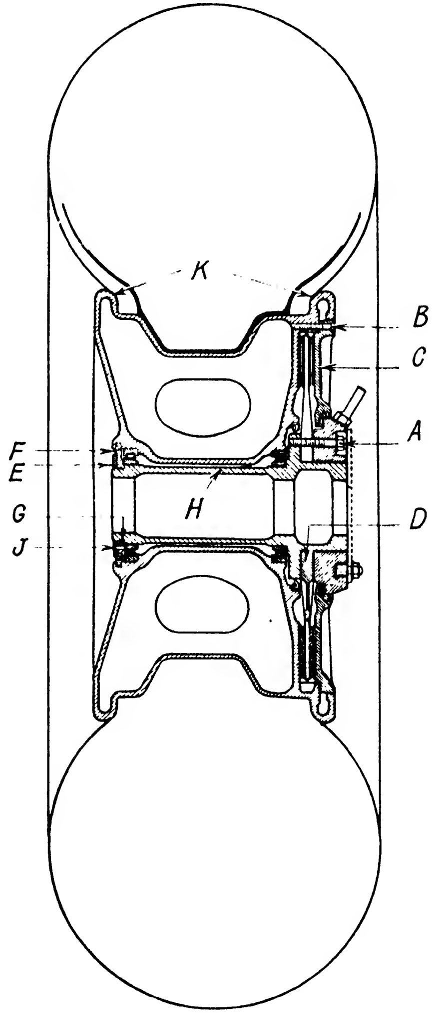



FIG. 46. SECTIONAL ILLUSTRATION OF AVERY WHEEL AND BRAKE UNIT

Situated within the two half-diaphragms is a resilient expansible capsule of special material which is inert to oil or other fluid. The diaphragms have a certain degree of flexibility, and when pressure is

applied to the brake system they are forced apart by the capsule, and in this way the friction surfaces make contact with the rotating linings of the wheel.

The wheel is carried on the hub sleeve by roller bearings, and on assembly the hub is packed with grease, which only requires to be replenished at long intervals. The wheel is held to the sleeve by means of the

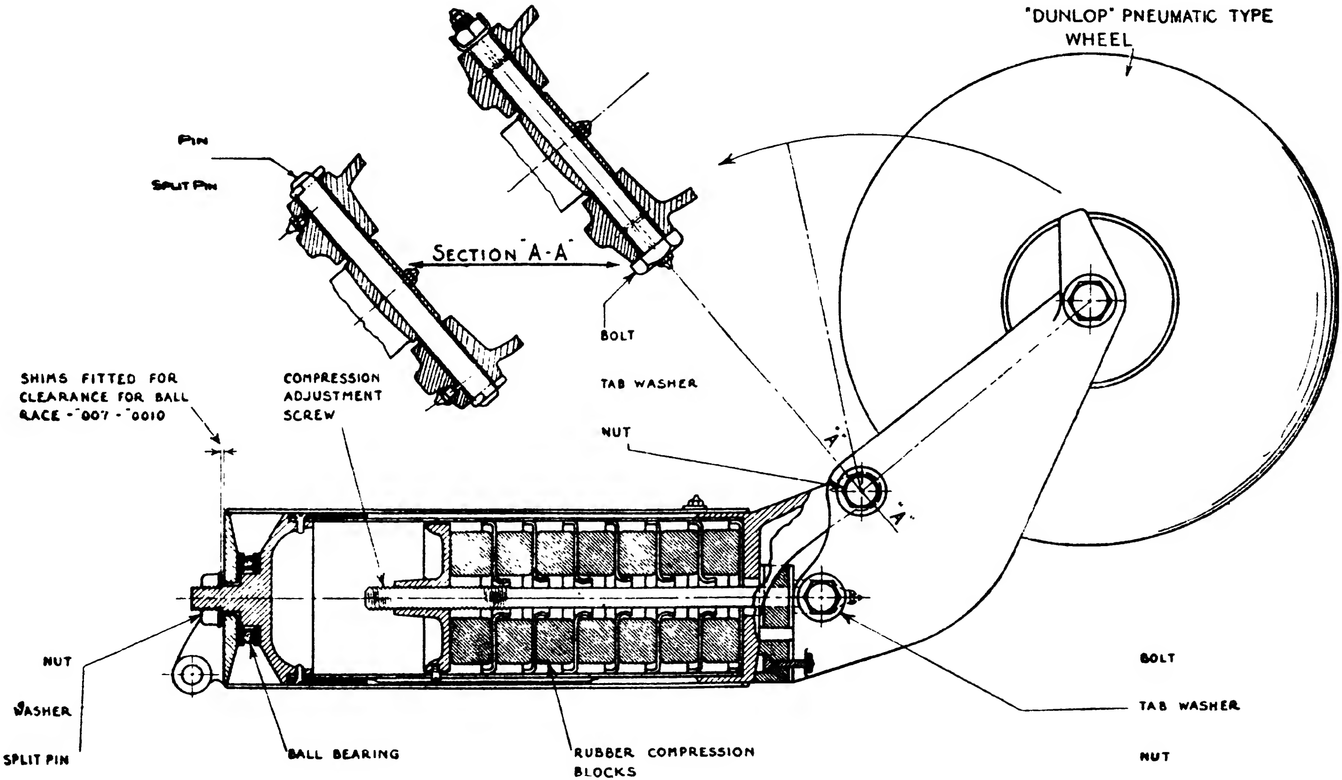
FIG. 47. AVERY AIRCRAFT WHEEL AND BRAKE

screwed nut *G* and lock washer *E*, both of which are secured against any possibility of rotation by the screws *J*. A felt seal is provided at *F*. No adjustment is necessary.

## 10. MISCELLANEOUS GEAR

### Shock-absorbing Devices

The principle of undercarriage shock-absorbing struts is the provision of a cushioning action combined with damping. The cushioning medium, which wholly supports the aircraft on the ground, may be rubber, steel springs, or compressed air. In order to damp the motion either a mechanical




(A.7) FIG. 48. DE HAVILLAND COMPRESSION STRUT

friction device or an arrangement whereby oil is forced through a restriction is used.

A type of compression strut, Fig. 48, that has been very successful on a number of light aircraft (de Havilland), consists of a number of rubber blocks arranged in two telescopic tubes, so that the rubber is compressed when the load is applied, i.e. when the machine lands. The maintenance of this type is as simple as the design, regular lubrication of the moving parts at regular intervals (consult airframe maintenance schedule) being all that is required. Test the action of the shock-absorbers, daily, by rocking the machine; when released it should quickly come to rest on an even keel. If it is noticed that the shock-absorbers have lost their resilience, or the pilot reports that the undercarriage is "hard," check the air pressure in the tyres. Modern "low pressure" tyres play a big part in the shock-absorbing effect of undercarriages and the pressure should be correct (as given in the handbook) for the load carried. It may be, however, that the rubber has deteriorated in the shock-absorber struts, as it will do in time. The machine should be jacked up and the free movement of the struts noted. If this seems excessive the rubbers have probably become compressed, and the makers should be consulted with a view to obtaining new ones and instructions as to how to fit them. Some shock-absorbers of this type have provision for taking up the play, but if the rubber has deteriorated this will not effect any improvement.

The steel spring and friction damper type of strut is shown in Fig. 49 and little need be added about it. The maintenance and daily inspection is similar to the previous type.

The modern trend is towards compressed air with oil damping. There are a number of different makes operating on this principle, one of which, the Lockheed, is here described.

The strut is of very simple design, using two tubes made to telescope one within the other, combining the principle of hydraulic fluid damping with air springing and cushioning for taxying purposes.

The construction is mainly two

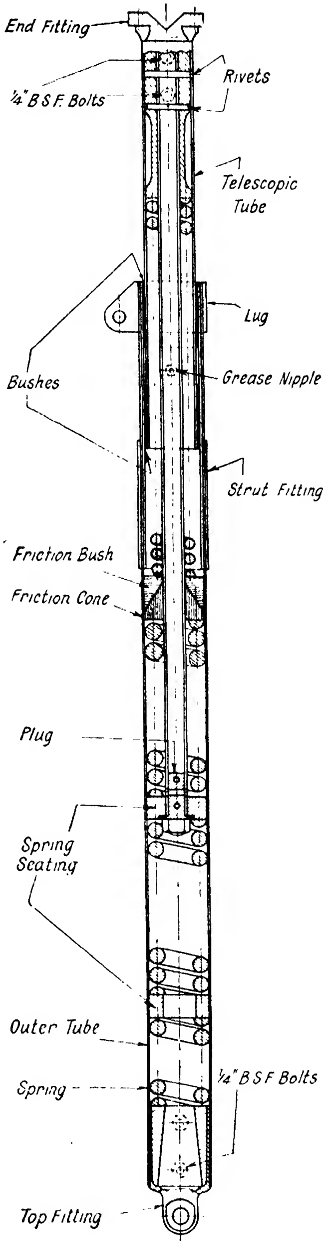



FIG. 49. STEEL SPRING AND FRICTION DAMPED TYPE OF STRUT

drawn high tensile steel tubes with aluminium alloy internal parts.

Special rubber glands are used on all seals, both for the fluid and for the air. The plunger tube has a chromium deposit on the outside and carries on its upper end a dural piston; alternatively, a bronze piston or a dural piston with a bronze bush attached; the latter is fitted with special glands and a flutter plate valve, which carries the fluid orifice; a piston cap and circlip, which locks the cap in place.

To make it possible to hold the fluid in the cylinder tube above the air in the plunger tube, a floating piston or separator is used to divide the fluid and air. The floating piston also carries special glands.

The cylinder tube is sealed at the top end by means of an oil head which carries a gland and is also fitted with two fluid plugs for the purpose of servicing the strut. The lower end of the plunger tube is sealed with an air head, which carries a special gland and an air valve for the purpose of inflating the strut. A light alloy wheel fork fits over this end of the plunger tube; on the lower end of the cylinder tube is a mid-section dural fitting which carries a wiper seal to remove foreign matter from the plunger tube before it enters the cylinder tube, and also carries the upper half of the torsion hinge; the lower end of the torsion hinge is attached to a boss on the wheel fork.

When an end load is placed on the strut (see Fig. 50) the plunger tube to which is attached the piston, is forced upwards through the fluid; the fluid above this piston is thus displaced and forced through the six large holes in the piston cap and the hole in the flutter plate valve which is the fluid orifice, and determines the amount of energy which the strut will absorb. As the fluid forces its way through this plunger head into the plunger tube, it impinges on the upper side of the separator or floating piston and forces it down the plunger tube, and thus compresses the air in the lower portion of this tube; the displacement of the fluid by the piston is regulated by the hole or fluid orifice in the flutter plate valve.

When the load is taken off the strut, the compressed air in the plunger tube forces the separator upwards, this forces the fluid in the plunger tube back into the cylinder tube and thus extends the strut to its fully extended position. The action of this fluid being forced upwards drives the flutter plate valve against the piston cap, blanking off the six large holes previously mentioned, leaving only the small hole in the centre of the piston cap for the fluid to return to the cylinder tube. This small hole in the piston cap gives the damping effect which prevents the strut extending too rapidly and so causing the aircraft to bounce. The strut extends at approximately one-half the rate at which it is permitted to close under the severest landing conditions.

### Daily Inspection

With the machine at rest on level ground, examine the plate fixed to the lower sliding portion of the fairing on which are marks indicating—

"Light Load"
"Full Load"

1. The bottom edge of the fixed part of the fairing should be in line with the mark which shows the loading of the machine at that time.

2. If the strut is shown to be compressed or extended more than normal for this load, depress the corresponding wing tip and allow it to spring up without assistance. This should overcome any tendency for the strut to stock, due to friction, and applies particularly when the strut is new.

(*a*) Where the strut remains over compressed and will not spring back, inflate as described below.

(*b*) Where the strut remains over extended, release the excess air

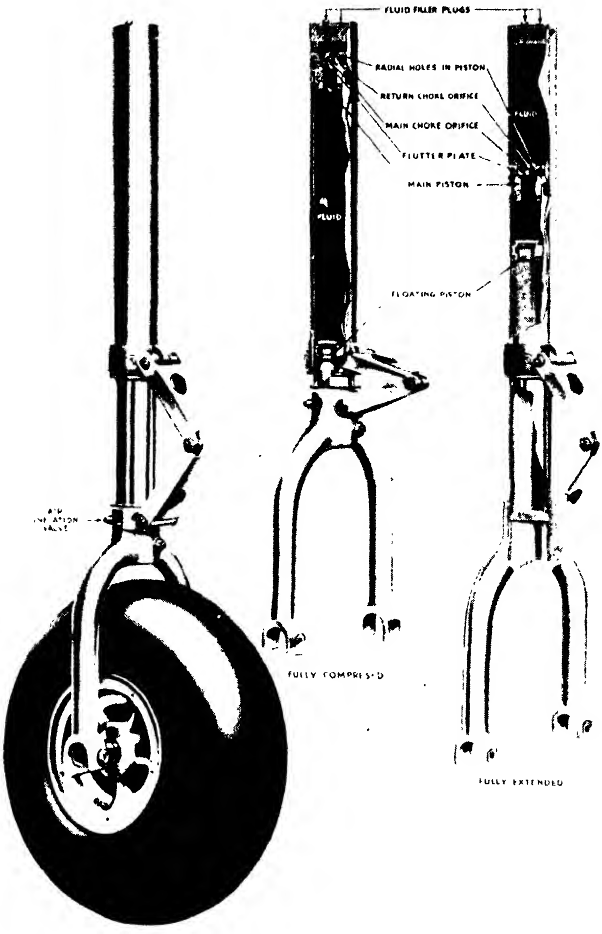



Fig. 50. Lockheed Airdraulic Strut

pressure by depressing the air valve needle until the strut assumes the correct position, after depressing wing tip as above.

(*c*) Where inflation or deflation fails to bring the strut to the correct position, deflate, refill with fluid, and re-inflate as described below.

### Fault Finding

If the strut is in the correct position as shown by the markings on the fairing, but the machine wallows excessively when turning and is slow in recovery, deflate, refill with fluid, and re-inflate as described below.

If after following the above procedure, the strut fails to function correctly consult the manufacturer.

RECHARGING

*To Inflate*

1. Remove the air valve cap and connect the special air pump provided.

2. (*a*) Inflate until the markings on the fairing show the position of the strut to be correct for the load the machine is carrying at the time. Depress wing tip and allow it to spring up without assistance to check that the strut is not sticking.

(*b*) For more accurate results, jack up the machine until the wheel is well clear of the ground and inflate to the correct pressure which is given on the name-plate on the strut and which should be checked by a screw-on type of gauge, making sure that the strut can extend fully with the tyre clear of the ground. This pressure is correct for all loads.

3. Replace the air valve cap.

4. Examine for air leaks around the air valve.

5. Occasionally examine strut for any signs of fluid leaks. If fluid leaks appear to be excessive, refill with fluid as below.

*To Fill with Fluid*

1. Fill fluid gun provided with special Airdraulic fluid. Operate gun slowly during filling to avoid sucking in air. If the fluid gun has not been used recently it should be primed as far as possible to soften the glands before attempting to fill.

2. With the whole weight of the machine on the wheels deflate the strut by reversing the air valve cap which will keep the air valve needle depressed. It is most important that the strut be fully compressed and the valve needle depressed during the whole filling period.

3. Remove one fluid plug and insert the fluid gun in orifice. Force fluid from the gun until no more will enter. This will require considerable effort.

4. Remove the second fluid plug and gently force fluid from the gun until a clear stream, i.e. free from air bubbles, emerges from the orifice.

5. Remove the gun, screw both fluid plugs firmly home, and replace the plug locking wire.

## Tail Skid

Tail skid types vary. A tail skid usually consists of a simple lever of the first order, the fulcrum of which hinges on a post or tripod arrangement fixed in the fuselage and having a shock absorbing medium for balancing the load at one end and a hard-wearing shoe at the other. The skid may be fixed, or may be freely tracking, or may be controlled partially or wholly in unison with the rudder.

The skid should be examined for buckling or fracture, the fulcrum points for slackness, struts or stays for bending, attachment lug holes for elongation, pins for shear, collars and bearings for wear, the shock-absorbing medium for general soundness, and the whole for general locking and security.

The tendency upon modern aircraft is to incorporate a small oleo-pneumatic strut (see "Shock Absorbing Devices") in conjunction with a tyred wheel (see "Wheels" and "Tyres").

## Tyres

The purpose of the aeroplane tyre is to interpose a pneumatic cushion between the aeroplane and the ground surface and to prevent undue shocks being transmitted to the aircraft, i.e. to minimize irregularities when taxying to take off, or in the final run after landing, and to act as a shock absorbing medium when the aircraft first touches the ground on landing. The successful use of pneumatic tyres depends upon the maintenance, whether the tyres be in service or standing by, of the correct inflation pressure for the load as recommended by the manufacturers.

## Maintenance

(*a*) Excessive wear may be due to the wheels not being in line.

(*b*) It is harmful to allow tyres to stand or to become bespattered with oil or grease.

(*c*) Tyres become badly cut about from flints and other sharp objects. The covers should be periodically examined for deep contusions.

(*d*) In some cases the inner plies of the covers break down and may give rise to swellings. Should a hand lightly passed over the cover be sensible of such swellings the cover should be removed, and if fractures are in fact existent a new cover should be fitted.

(*e*) Tyres under ordinary and normal circumstances should be taken down for general examination and for inspection at any signs of perishing.

(*f*) Tyres preserve their structure and resiliency best in a cold and damp atmosphere; so far as conditions permit. therefore, and without prejudice to other parts of the aircraft, continued heat and dryness should be avoided.

(*g*) Should the aircraft be stored, jack up so that no weight remains on the tyres. If this is inconvenient, move the aircraft periodically to ensure a fresh area tyre is in contact with the ground.

The complete tyre should always be maintained in a good and sound condition. It should be borne in mind that a tyre-burst or failure whilst an aircraft was landing or taking-off at speed would be a dangerous and hazardous happening.

## Wheels

Care should be taken during removal or fitting operations to avoid any damage to the protective surface coating. The bearings should be re-packed with grease from time to time, and in the case of wheels fitted with brakes more care is necessary with lubrication. Over-lubrication may result in grease finding its way on to the brake drum and impairing the efficiency of the brake.

## Flotation Bags

These may be fitted in land aircraft to provide a period of buoyancy in the case of a forced descent upon water. The bags are interconnected by piping, and remain open to atmospheric pressure, a stop-cock being closed by hand immediately prior to the "landing." The material from which the bags are made is a rubberized fabric, which should be examined for deterioration when in use. Points of likely damage or chafing against the structure should be suitably taken care of. The system should be pressure tested to ¼ lb. per sq. in. (or 7 in. head of water) by means of a U-tube. The fall in pressure must not exceed 3½ in. of water during test.

A suitable period should be allowed to elapse between the initial imposition of pressure and the test, to permit the temperature of the air in

(Extracts from A.I.D Leaflet 11A, by courtesy of the Controller, H.M.S.O.)

the system to equalize with that of the shop or hangar. Any drop in pressure observed should be corrected before the actual test is commenced. Care should be taken that the air bags are not exposed to radiant heat (direct sun's rays) during test. Bags may be individually tested by the application of soapy water (which must afterwards be properly washed off) around seams.

## 11. GENERAL MAINTENANCE AND MINOR REPAIRS

### Cleanliness

The fabric of the aircraft must be kept clean and free from oil, in order to avoid deterioration. To remove dirt and oil from the fabric, rub it well with a piece of waste or rag soaked in warm soapy water. Having removed all dirt and oil, wipe the fabric with a piece of dry cloth.

Mud thrown on to the fabric by the wheels of the undercarriage should not be allowed to dry, but should be removed as soon as possible. If, however, it has become dry, it should be taken off with warm water and not scraped off, as the fabric is liable to be damaged by scraping.

### Control Wires

After every flight pass the hand over the control wires and carefully examine them near pulleys and fairleads. Even if only one strand is broken the wire must be changed. The aileron balance wire on the top plane must not be forgotten. Once a day try the tension of the control wires by moving the control levers about smartly.

### Wires

See that all wires are kept well greased or oiled, and that they are adjusted to the correct tension. When examining the wires, make sure that the aircraft is on level ground, as otherwise it may get twisted, throwing some wires into undue tension and slackening others. The best way, if you have time, is to pack the machine up into its "rigging position." Should a slack wire be discovered it does not follow that this should be tensioned. The aircraft should be placed in rigging position and the cause traced. It may be that the opposite wire is stretched, the fitting pulled, or a component bowed, etc.

Carefully examine all wires and their connections near the airscrew.

### Distortion

Carefully examine all surfaces, including the controlling surfaces, to see whether any distortion has occurred. Should distortion be discovered the defect must be very carefully traced and rectified. It may be that a wire has been unduly stressed, causing a rib to buckle. Slackening back the wire would not effect the repair as the rib would have become fractured, or the glue or securing loosened.

### Undercarriage

Constantly examine the alignment and fittings of the undercarriage, and the condition of tyres, shock absorbers, and the tail skid.

Special care should be exercised when examining the "Oleo" type undercarriage.

### Cleaning of Metal Fittings

When metal fittings require cleaning, all forms of scraping, such as rubbing with emery cloth or a wire brush, should be avoided. A paraffin bath and a soft brush or rag soaked in paraffin should be all that is required.

When removing paint or varnish, no abrasive methods should be employed, but the covering material should be softened with the varnish remover and rubbed with a rag soaked in this solvent. Stove-enamelled fittings are not usually treated with zinc or cadmium, and therefore the normal methods of removing stove enamel may be employed. After removal of the defective paint or varnish, all fittings should be re-coated with the appropriate protective covering with the exception of the side and bottom fuselage cowlings and the metal parts of undercarriages and radiators. These parts, if desired, need not be re-painted, but may be kept clean and bright by using metal polish or an oil-soaked rag.

## Inspection Doors in Planes

Metal inspection doors in main planes should be very closely watched, especially if situated in the slipstream region, as fastenings which would normally be regarded as quite secure may possibly become detached through vibration and the effects of the slipstream. Should this occur the inspection door may fly back with considerable force, involving a possible injury to the pilot or the fouling of control mechanisms.

## Rip Off Patches on Planes

Inspection doors are usually provided only at those positions where frequent inspection or lubrication of the internal fittings is required. Where only occasional inspection or adjustment is required for internal fittings, such as bracing wires, a special form of patch is used which is capable of being torn off and renewed as necessity demands. There are several types and shapes, but in all cases a light frame is secured to the fabric covering of the wing and the fabric enclosed by the frame cut away, thus providing a hole with a non-frayable edge. A covering patch of frayed fabric large enough to envelop the frame is then doped on to the plane over the hole. When it is necessary to place a rip off patch on a plane, the frames should preferably be of the circular type with an internal diameter of 4½ in. to 5 in., but other shapes can be adopted to suit special conditions.

## Care of Shock Absorbers

The shock absorber legs on the undercarriage of any aeroplane should be of equal length under any given load, and where this is not the case, an examination should be made to ascertain the cause of the unequal extension. Gauge marks are normally provided to indicate the approximate safe minimum length.

## Repairs and Maintenance

After an aeroplane has been assembled and flown, there are manifold duties connected with the maintenance of the aeroplane in a sound and airworthy condition. This entails a regular and systematic examination of all parts, with the consequence that adjustments and minor repairs are found necessary from time to time, quite apart from the repairs necessitated by a more or less serious mishap to the aeroplane such as might be occasioned by a forced landing. If an aeroplane is seriously damaged, but not sufficiently for it to be struck off charge, it is usual to strip the aeroplane completely, dismantle the damaged portion, substitute complete components for those badly damaged, and repair the parts which are only slightly injured. The repair and maintenance notes for the type usually specify the limit of repairable damage, and the details provided generally cover all normal eventualities. The repair and maintenance notes are either issued separately or incorporated in the aeroplane handbook.

The methods of repair vary in accordance with the type of construction used, and it is obvious that a repair which is suitable for one type of aeroplane will in most cases not be suitable for another type. It is highly important, therefore, that only those repairs should be used which have been approved for the particular type of aircraft, and which are enumerated in the repair notes.

### Rigging Allowances

Rigging notes and instructions generally give the angles and dimensions in exact figures, but in practice it is seldom possible to work to the exact dimensions given. A tolerance is therefore permissible on all dimensions.

The allowances to be made vary with different aircraft, obviously depending mainly on the type and size of the aeroplane and the magnitude of the dimension.

The utmost care must be taken to avoid damage to the structure owing to an attempt to work to too strict a tolerance; on the other hand, no effort should be spared to obtain the closest approximation to the rigging dimensions that the normal adjustments will allow.

### Inspection

After re-assembly, necessitated by repairs, the aeroplane should be completely inspected before it is passed as fit for flying. The inspection should be made methodically and in accordance with a system. The system usually adopted is to divide the aeroplane into a number of logical and convenient groups, and deal with each group in a definite order. The grouping normally employed is: undercarriage, fuselage, tail unit, cock-pits, mainplanes, airscrew, and general. During the inspection of each group, the inspector should, as far as the group lends itself to such procedure, always go round it in an anti-clockwise direction, examining each individual part in detail as it is encountered.

### Detachable Fairings

When the flush fitting type of cowling clip is used, special precautions must be taken to ensure that the clips are actually securing the fairing to the structure, as the fairing is in a dangerous condition if one of the clips does not catch as it should. It is usual to arrange for the screw-driver slots or other operating mechanism to be all in one direction so that the position of the catch can be ascertained at a glance. If this has not been arranged, suitable marks should be made on the clip, the marks being all in one direction when they are attached.

### Protection Against Corrosion

One of the greatest enemies of metal aircraft parts is corrosion. An infallible and everlasting remedy for corrosion which is of practical utility has yet to be found for the majority of ordinary metals. The greatest advance within recent years was the introduction of stainless steel. The use of this material, of which there are several varieties, appears to be a solution of many problems connected with corrosion. Materials used on aircraft which demand the greatest care from the aspect of corrosion are ordinary steels and light alloys. Steels by themselves do not corrode at a greater rate than many other metals, but on account of their greater tensile strength they are generally used in much thinner gauges than other materials, and are therefore more susceptible to deterioration owing to this cause. Light alloys which have a basis of aluminium or magnesium are inherently unstable, and given an opportunity will corrode very

quickly. The corrosion which occurs in these materials is not always attributable to exterior causes, but it may be due to the interaction which occurs, due to impurities in the metal. For both steels and light alloys the basic principle of protection against corrosion is to exclude the air from contact with the metals. If, therefore, corrosion is to be avoided, it is imperative that the protective covering should remain intact, or if, owing to mishandling or service usage, the protective covering has become damaged, it should be renewed immediately. The usual protective media employed include paints, varnishes, enamels, sherardizing, hot galvanizing, coslettizing, cadmium plating, anodizing, and metal spraying, all of which have been devised with the object of defeating corrosion.

## 12. AIRCRAFT FIRE FIGHTING EQUIPMENT

It is now necessary for a ground engineer to have a knowledge of fire fighting equipment and its installation tests requirements. A new extinguishing system for fighting fires in aircraft is the Graviner system, and its purpose is to put out fires in the engine compartments if a crash occurs, and to enable fires to be extinguished while in flight, or if the aircraft overturns in making a forced landing. The extinguishing medium used is pure methyl-bromide contained in copper bottles under a pressure of 60 lb. per sq. in. When this fluid is discharged, it immediately evaporates with an intense cooling effect. The engine and the interior of the cowling are inundated with the chemical, so that hot metal parts become instantly reduced in heat below the ignition point of petrol and the fire is smothered. Portable extinguishers can also be fitted for use by hand in other parts of the aircraft. The Graviner system is operated by four simple switches; one, called the (1) crash switch, acts with the speed of a gun the moment an aircraft crashes (see Fig. 50A). The pendulum inside the case continues to swing forward by inertia after the forward movement has been arrested by the aircraft striking the ground. This releases the spring-loaded arm, which swings up, causes an electric contact to be made to ignite an explosive charge which causes the stopper of the bottle to be blown out, and this operates the extinguisher. The (2) Gravity Switch operates when an aircraft inadvertently turns over on its back in landing. The heavy arm falls by gravity as the switch turns over and releases the contact arm which causes the switches to make contact. The switch is so connected in the electrical circuit that it does not work if the aircraft turns over while performing aerobatics. The (3) Flame-operated Switch comes into action when the temperature round it reaches 200° centigrade, while the (4) Push Button switch is operable by manual control should the pilot wish to flood his engine compartments with methyl-bromide just before an expected crash or for any other emergency reason.

### Installation Inspection and Tests for Graviner Automatic Fire Fighting Equipment

1. *Extinguisher.*

*Mark* II (not suitable for hand operation).

The extinguisher bottle can be withdrawn from its bracket for check weighing. The empty weight of the bottle is stamped on the handle and the charge weighs 6 lb. and if loss of weight has occurred the bottle must be replaced by another.

To detach bottle from its bracket remove the electrical plug-in socket and release the wire clip.

If the extinguisher bottle is discharged the bottle must be replaced.

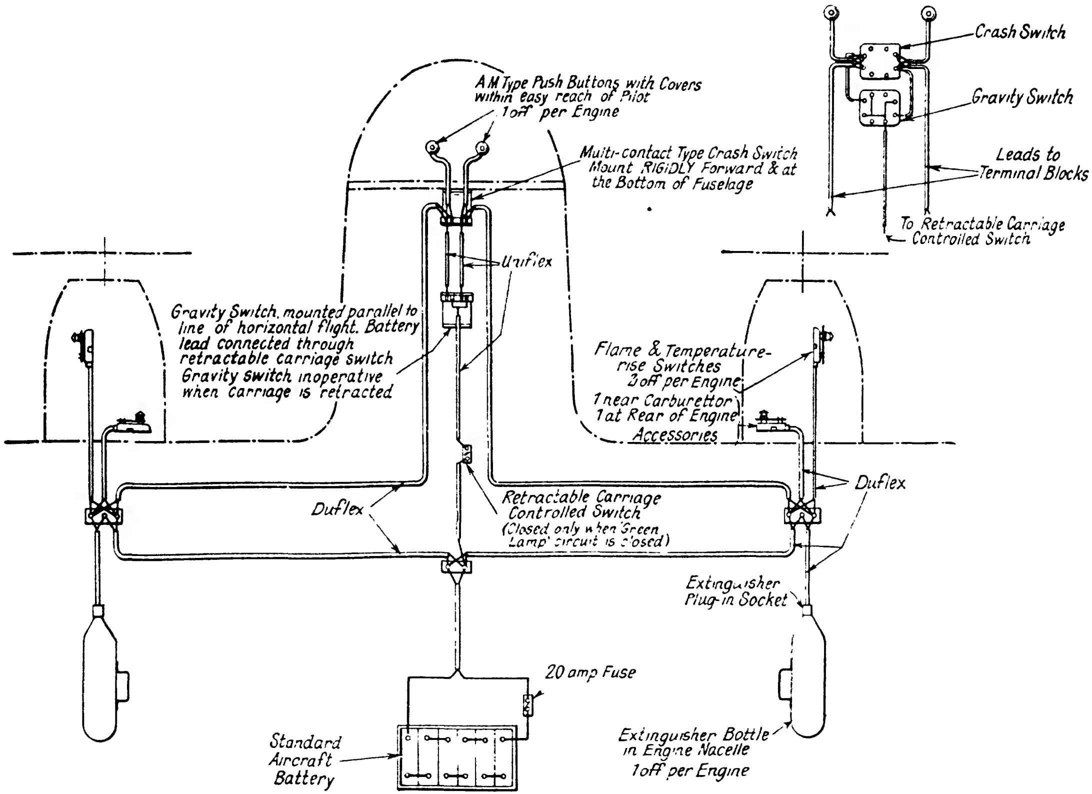



FIG. 50A. GRAVINER AUTOMATIC FIRE FIGHTING SYSTEM

Brackets must be carefully inspected for signs of distortion after discharge of the bottle and replaced unless bottle is firmly clamped between the junction box and the rear curved portion of the bracket. *Remove blown-out portion* of bottle from interior of junction box after discharge.

*Mark* I (suitable for hand operation).

To detach bottle from bracket push spring urged clip on bracket clear of small handle on bottle to avoid accidental discharge and remove electrical plug-in socket releasing wire clip.

To operate by hand release clip and pull extinguisher out of bracket to cause fracture of pipe and automatic discharge of extinguisher.

2. *Electrical Switch and Circuit Tests.*

Before re-inserting bottle after weighing test, or if replacing, test the electrical circuit by inserting an electrical lamp with a suitable plug into extinguisher socket. In the case of multi-engined aircraft all bottles must be removed or disconnected when the tests are carried out and lamps inserted in all sockets. With all electric switches at normal check that all lamps are extinguished.

3. *Flame Switch Test.*

With lamps in extinguisher plug sockets; remove securing wire on top of switch and unscrew the plug-like fitting on the flame switch to permit the contacts to close and check that lamp lights. When resetting the flame switch ensure that lamps extinguish and screw plug-like fitting down by not less than two turns and until it is tight, and secure with wire to avoid accidental loosening due to vibration. Repeat with other flame switches.

4. *Push Button Switches.*

With lamps in all extinguisher plug sockets press each switch in turn and see that corresponding lamp lights.

5. *Crash Switch.*

With lamps in all extinguisher plug sockets test as follows: Rotate knob on switch case so that arrow points to Trip, press firmly and switch will be tripped with a click all contacts closing. Check that all socket lamps light. To reset rotate knob so that arrow points to Set, rotate square spindle in clockwise direction by resetting disc as far as it will go (about 120°) and press knob firmly down until pendulum engages mechanism when square spindle is released and switch is set all contacts open. Give switch terminal block a light blow by hand to ensure mechanism is properly set. Check that all socket lamps are extinguished.

6. *Gravity Switch.*

To test the circuit of the gravity switch rotate square spindle in anti-clockwise direction by key disc or pliers as far as it will go (about 60°) and see that all socket lamps are lighted. Remove key disc, etc., to permit instrument to assume normal position and check that all lamps are extinguished.

7. *Test electric circuit for resistance as for electric lamp wiring*

On completion of tests plug the terminal socket to the extinguisher, inspecting the plugs and socket metal parts for signs of corrosion, etc. With battery disconnected test for circuit continuity by connecting a high resistance voltmeter (1000 ohms) in series with a low voltage dry cell

($1\frac{1}{2}$ volt) to extinguisher leads on terminal block and note flick of pointer indicating circuit continuity over leads, plug and fuse. Secure wire clip trip mechanism by wiring to prevent the trip from releasing the clip due to vibration set. Also secure plug-in socket by cord, tape or wire to terminal block to prevent accidental disconnection and to ensure good contact.

8. *Perforated Piping.*

The piping requires periodic cleaning (100 flying hours period or so). This may be done by detaching pipe fittings from fire-proof bulkhead fitting and if pipe ends are closed over it is advisable to remove the closed end portion and fit a standard Air Ministry union nut and fitting end blanking device. With both ends open apply air pressure by tyre pump or compressed air supply to blow out oil and dirt. Secure piping to bulkhead fitting and close end of pipe by blanking fitting to ensure that liquid is sprayed from the perforations and not from an open-ended pipe if the fire fighting equipment should be operated.

Pipe installations provided with air intake nozzles have a flexible pipe connection from the fire-proof bulkhead or from the extinguisher to the nozzle and the perforated piping extends from the nozzle. In some installations (Radial engines) only one nozzle is provided, in other installations (Cylinder-in-Line) there are two nozzles. These nozzles require cleaning and the small central screw with flats can be unscrewed and removed. Ensure that the helical groove in this fitting is clean. Also clean out central bore after removal of screw and push a $\frac{1}{16}$ in. drill through a central orifice to clean this out. Do not unscrew large screw with flats, this is a stud securing the nozzle to the air intake and this need not be removed. Reinsert small screw and screw up and secure by wire.

9. *Warning.*

If for any reason a fire extinguisher bottle is discharged by firing when removed from its bracket ensure that bottle head is held downwards facing a heap of sand, etc., as the metal stoppering device blows out with considerable violence and may cause damage and injury if permitted to strike any object or person.

## CHAPTER III

# HYDRAULIC EQUIPMENT AFFECTING THE SAFETY OF AIRCRAFT

THE actuation of aircraft retracting undercarriages and tail wheels and flaps, control trimming tabs, engine cowl gills, etc., by means of hydraulic jacks, has become increasingly popular, and this method of operation is being adopted by practically all aircraft constructors.

Probably the chief reason for this rapidly increasing popularity is the fact that one central power unit, namely the pump (which may be operated by the aircraft engine or by hand, or may be a self-contained electrically powered unit), can be used to control all the aircraft components just mentioned without the necessity for using torsion shafts, push rods or any other mechanical means of power transmission.

Again, the hydraulic control system offers an extremely simple means of gearing up or gearing down between the power unit and the final operating device without the use of worm shafts, gear wheels, or lever combinations, for it is only necessary to vary the piston areas of the different operating units in order to obtain the desired gear effect.

## 13. HYDRAULIC INSTALLATION

There are three main units common to all hydraulic installations used on aircraft. They are the pump which supplies oil under pressure to operate the system, the valve which controls the direction of flow of oil through the pipe lines, and the jacks which operate the various components.

Fig. 51 illustrates the simplest form of hydraulic installation suitable for operating either a retracting undercarriage or split trailing edge flaps.

This installation comprises a hand-operated pump (*A*), a two-way control valve (*B*), and a pair of jacks (*C*). The pump delivers oil under pressure to the jacks via the control valve which is so constructed that it allows the operator to change the direction of flow in the jack pipe lines, thus permitting extension or contraction of the jacks at will.

Fig. 52 illustrates a simple hydraulic installation in which the required oil pressure supply is provided by an engine-driven pump.

For simplicity, only one undercarriage jack and one flap jack are shown in the diagram but tappings may be taken off the pipe lines to operate any number of jacks.

During the whole time that the engine is running, the engine pump (*A*) delivers oil continuously to an automatic valve (*B*) which normally allows the oil to flow direct to the reservoir via filter (*C*). Under these conditions the pump is idling at no pressure.

The pilot is provided with a lever control (*E*) for operating the undercarriage and flaps.

The control lever is connected to the distributor valve box (*D*) by a remote control such as push rods. The operation is as follows: to lower the flaps, the control lever is moved out of neutral to the gate position labelled "Flaps down" and this actuates the distributor valve so that the pipe (*G*) is connected to the pressure pipe (*O*), and the pipe (*H*) is connected to the return pipe (*I*). The automatic valve (*B*) instantly goes into action and the pump supplies oil under pressure to the flap jack.

When the jack piston reaches the end of its stroke, the automatic valve cuts off the supply and the pump then continues to circulate oil under no pressure to the reservoir.

To raise the flaps the lever is moved to the opposite end of the gate labelled "Flaps Up," and by this means the pipe (*H*) is connected to the pressure pipe (*O*) and the pipe (*G*) is connected to the return pipe (*I*), the cut-out valve again throws the pump into the circuit and oil is delivered

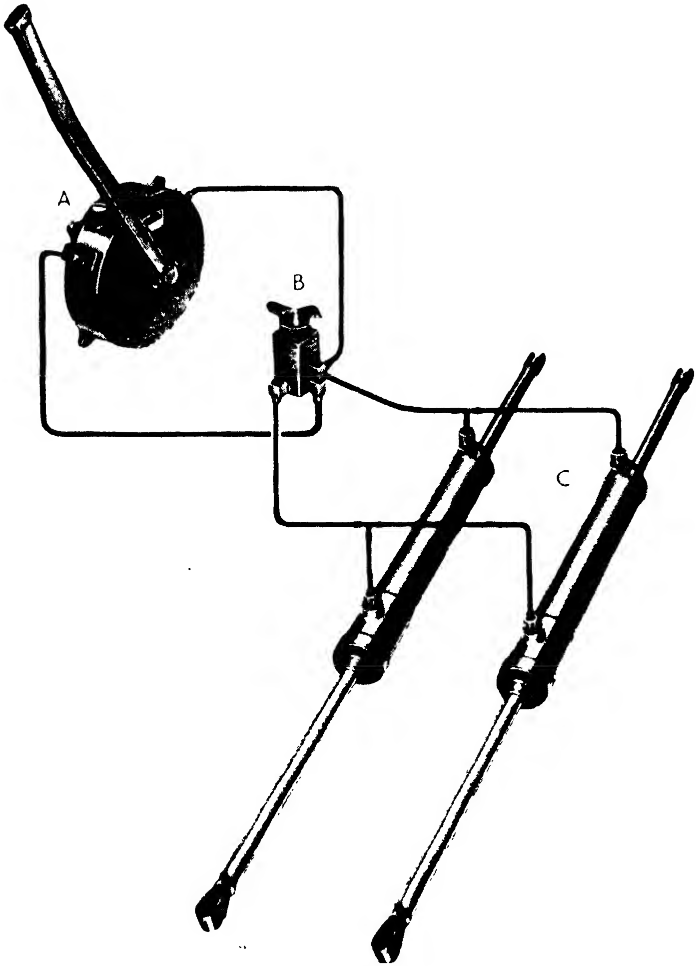



FIG. 51. HYDRAULIC INSTALLATION

under pressure until the jack has reached the end of its stroke. It should be noted that in this system the flap jacks may be stopped at any point throughout the length of their travels by placing the control lever in the neutral position, thus enabling the pilot to set the flaps at any desired angle.

The hand pump (*H*) is provided as a standby in case of failure of the engine-driven pump.

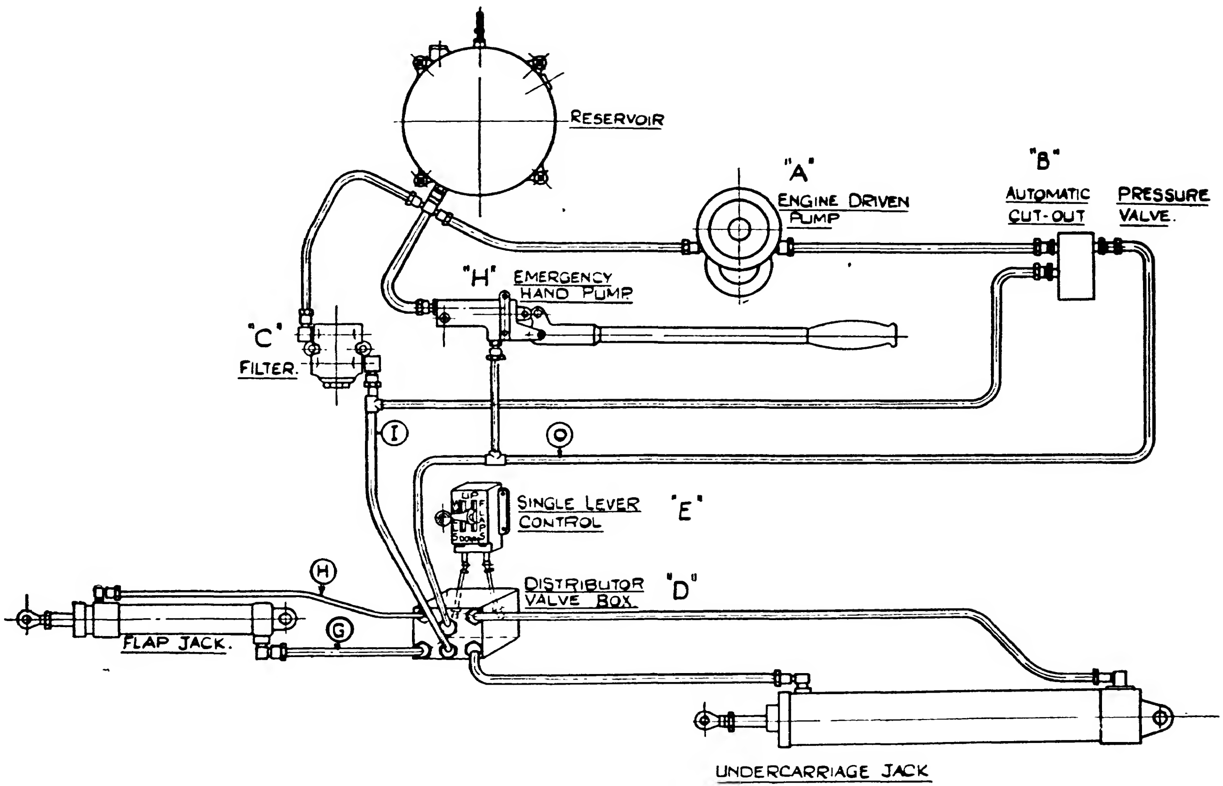



FIG. 52. "DOWTY" HYDRAULIC CONTROL SYSTEM

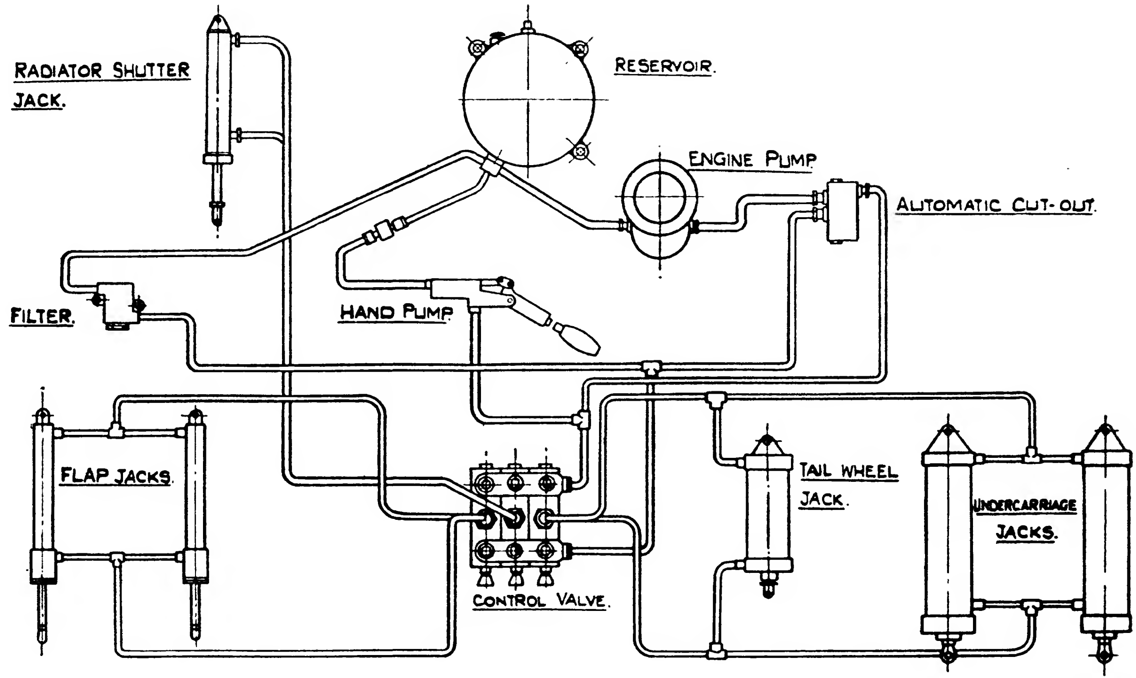



FIG. 53. LAY-OUT OF "DOWTY" CONTROL SYSTEM

To prevent undue pressures occurring in any of the pipe lines, owing to variations in temperature, the distributor unit is provided with automatic relief valves which compensate for variations in volume.

Fig. 53 shows a rather more complicated system, incorporating hydraulic undercarriage retracting jacks, a retracting tail wheel, jacks for controlling trailing edge flaps and a jack for operating radiator shutters.

The control valves are of a different type from those shown in the previous illustration and are actuated by push buttons. In this illustration the pipes from the jacks connect to the upper and lower faces of the valve body.

The power unit in this illustration is also an engine driven pump.

A Dowty control system which offers many advantages is illustrated in Figs. 54 and 55. This control enables the pilot to set the flaps in any desired position throughout their range of travel, not only at the take-off and landing settings but also at any intermediate angle so that the glide can be steepened or flattened at will.

A further useful feature is that automatic synchronization is provided for several flaps, as for example those fitted to a centre section and two outer wings.

It will be seen from the illustrations that the hand control lever actuates a valve which permits oil to flow into either end of the operating jack, and when the flap has reached a position corresponding with the setting of the hand lever the valve automatically cuts off the supply of oil to the jack and the flap is locked in position.

This control can also be arranged to allow the flap to blow up under excessive air load and return to its predetermined position when the load is reduced.

This pre-selector control has wide application for such services as the operation of radiator shutter jacks, landing, lights, etc., where predetermined intermediate settings are required.

## Automatic Cut-out

On the majority of hydraulic systems where an engine-driven pump is employed the pump is running during the whole time the aero engine is in use, but it is undesirable for the pump to deliver oil under pressure throughout this entire period. On the other hand, introduction of a clutch necessitates another operation on the part of the pilot to engage this when oil is required under pressure.

To overcome these two difficulties the automatic cut-out has been developed to enable the pump to idle at all times except when any of the hydraulic jacks are operated.

Fig. 56 shows a section through an automatic cut-out. Oil is fed from the engine pump to connection (*A*), and during operation of the jacks oil passes through connection (*B*) to the control box and from there to the selected pipe line. When the jacks reach the end of their travel the pressure rises momentarily and reacts on piston (*C*) causing this to move and compress spring (*D*). An extension (*E*) on the piston lifts the valve (*F*) from its seat and allows the oil supply from the pump to escape through connection (*G*) to the reservoir. Under these conditions the pump is idling and the only pressure in the circuit is that required to overcome the hydraulic friction in the pipe lines and filter.

Meanwhile, the valve (*F*) is still being held off its seat by the oil pressure behind piston (*C*). This condition holds good until the jacks are operated in the reverse direction, or some other jacks in the circuit are actuated.

Then, when the control valve is operated, the pipe lines holding high

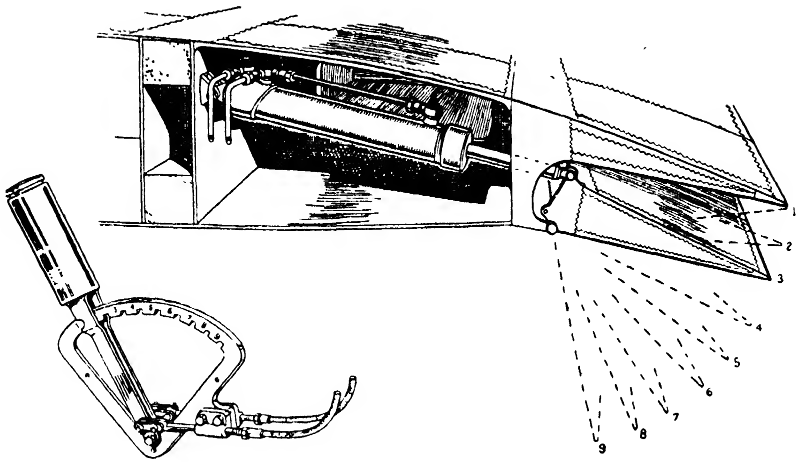



Fig. 54. "Dowty" Pre-selector Flap Control

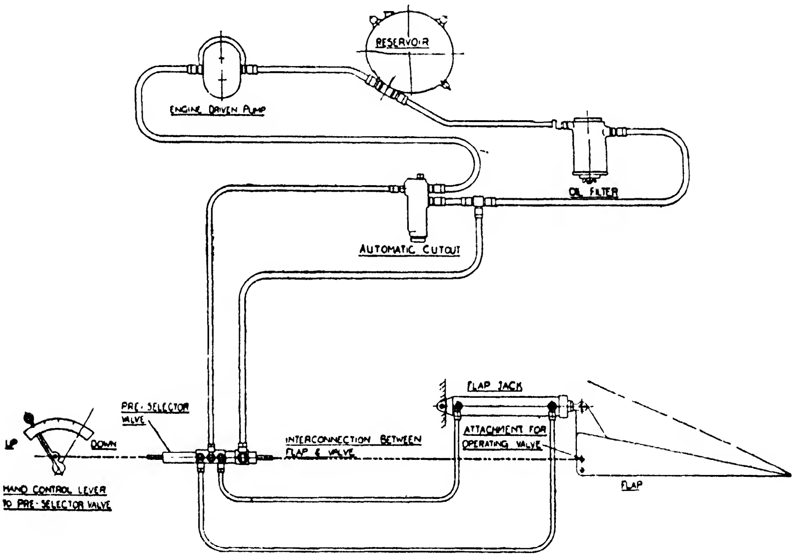



Fig. 55. Piping Diagram showing Operation of Flap with Pre-selector Valve

pressure are opened up to the reservoir with consequent loss of pressure behind piston (*C*), which then returns to its original position under the

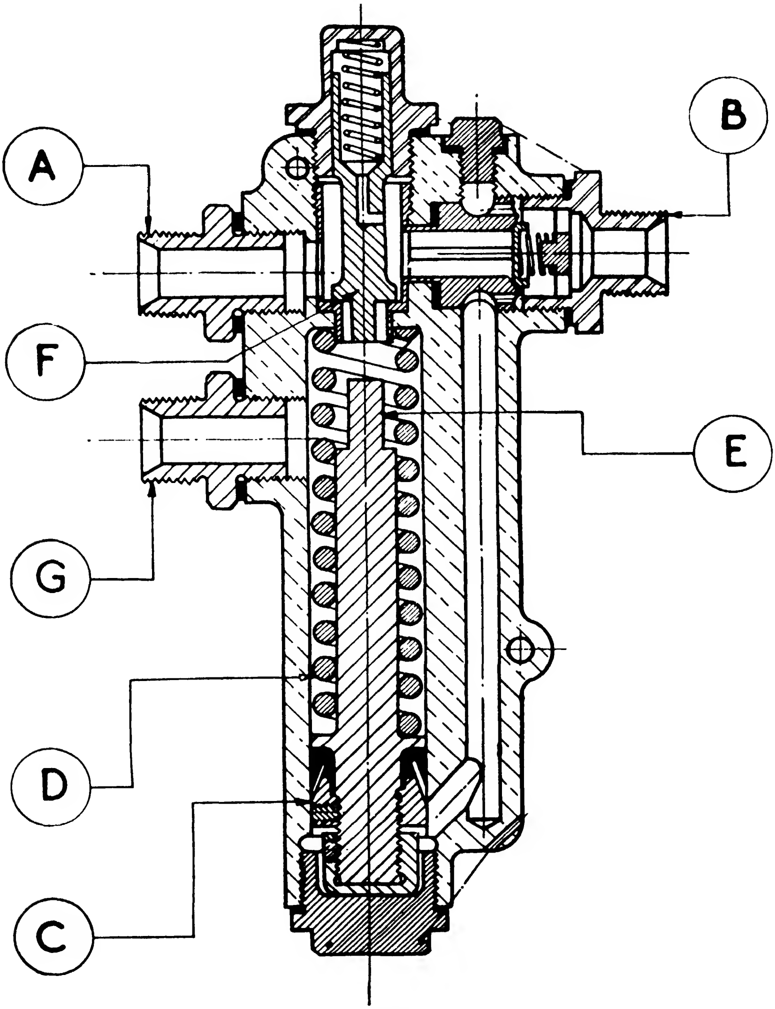



FIG. 56. AUTOMATIC CUT-OUT

influence of the spring, thereby allowing the valve (*F*) to reseat and close the oil return circuit to the reservoir.

Oil delivered by the pump is then compelled to pass through the cut-out and into the control valve, to actuate the jacks once again.

This automatic cut-out may be regulated to lift the valve (*F*) at any desired pressure, consequently it is possible to limit the maximum oil pressure in the circuit to any required figure.

Figs. 57 and 58 show conditions in the cut-out during travel of the jack piston and after the stroke is completed. In the diagram below and the one on the opposite page the automatic cut-out is shown provided with ball valves in place of the flat face valves shown in Fig. 56, but this change has been made merely for clarity.

It will be appreciated that any loss of pressure in the jack, or its

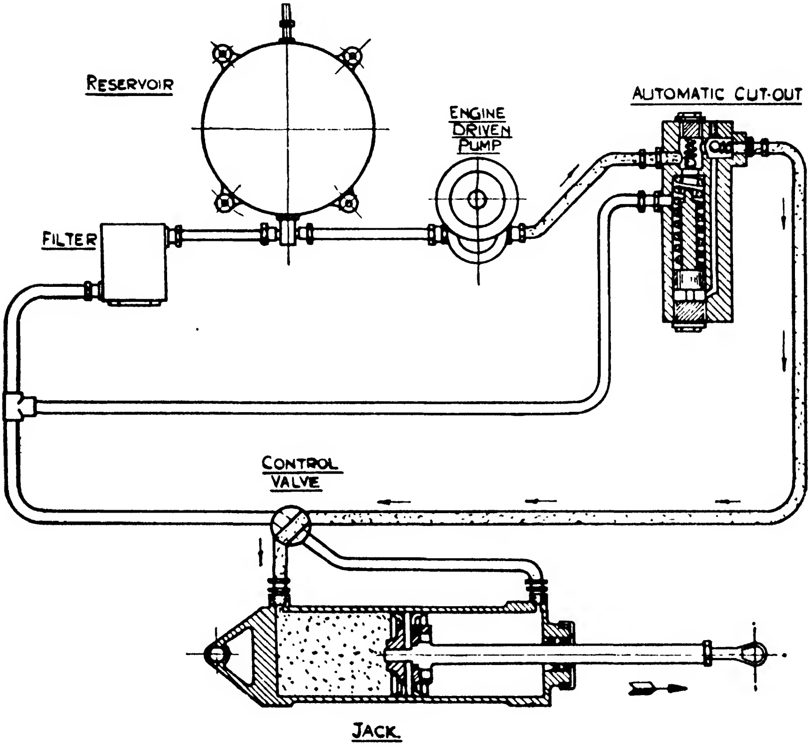



FIG. 57. CONDITIONS IN AUTOMATIC CUT-OUT DURING TRAVEL OF JACK PISTON

communicating pipe lines, causes the cut-out to revert to the conditions shown in Fig. 57 until the cut-out pressure is again reached.

## 14. SAFETY DEVICES

Some of the earlier designs of retracting undercarriages caused their constructors a great deal of anxiety, and the test pilots some harrowing moments, by failing to carry out their functions satisfactorily when required to do so, with the result that quite a number of aircraft fitted with these undercarriages have made abdominal landings.

The natural outcome was that designs were produced with various safety devices, and amongst these may be mentioned—

1. Emergency extension devices which would only be put into operation in the event of failure of the normal extending means.

2. Locks of various sorts to lock the undercarraige in the extended position.

3. Warning devices to prevent the pilot attempting to land with the undercarriage in the retracted position, etc.

Dealing with the first of these items, namely, the emergency extending devices, the hydraulic method of operation lends itself very readily to

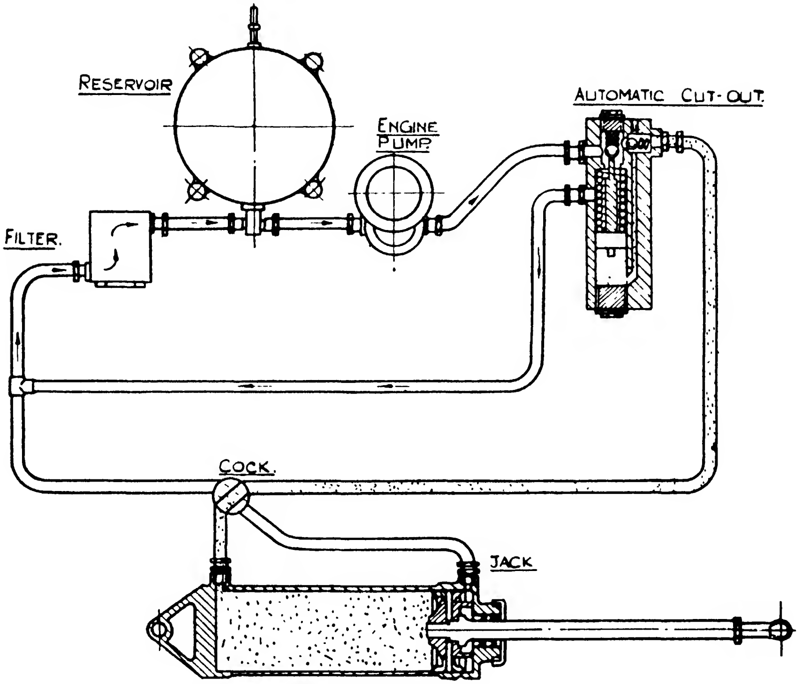



FIG. 58. CONDITIONS IN AUTOMATIC CUT-OUT AT END OF PISTON TRAVEL

an auxiliary form of extension, and it is proposed to describe a method of achieving this.

This consists of storing a charge of compressed air in a cylinder which is provided with an inflation valve and a pressure gauge, and from this cylinder pipe lines (which may be of a very small bore and are consequently light in weight) communicate with the jacks in such manner that when air is released from the cylinder it flows into the jacks and extends the undercarriage.

Fig. 59 shows a piping diagram in which the various units comprising the air emergency extending devices are featured.

Air is pumped into bottle (*A*) through a valve (*B*) to a pressure of approximately 1000 lb. per sq. in., by means of a compressor of the type used for inflating pneumatic shock-absorber struts, and the valve is then locked in the closed position. This is a ground operation which is independent of any air compressor on the aero engine, consequently engine failure does not put this emergency device out of action.

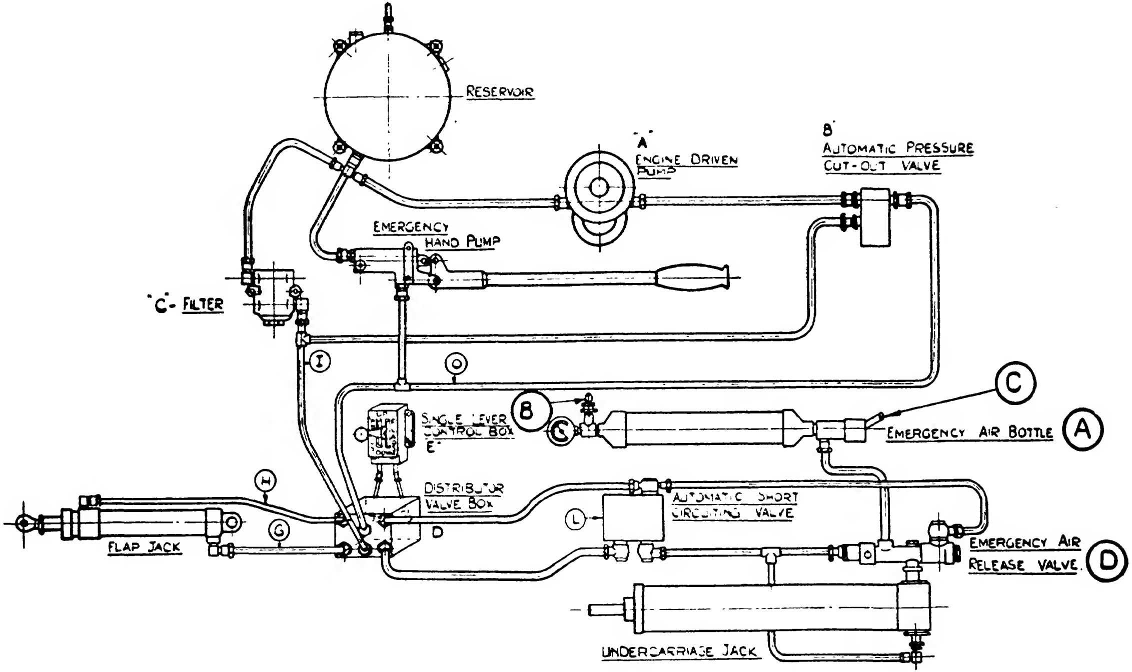



Fig. 59. Hydraulic System with Emergency Air Extension

To operate the emergency extension, lever (*C*) is pulled, and this opens a valve to release the air into the pipe lines.

Mounted upon the undercarriage jacks, or in close proximity to them, are air release valves which perform several functions. It will be realized

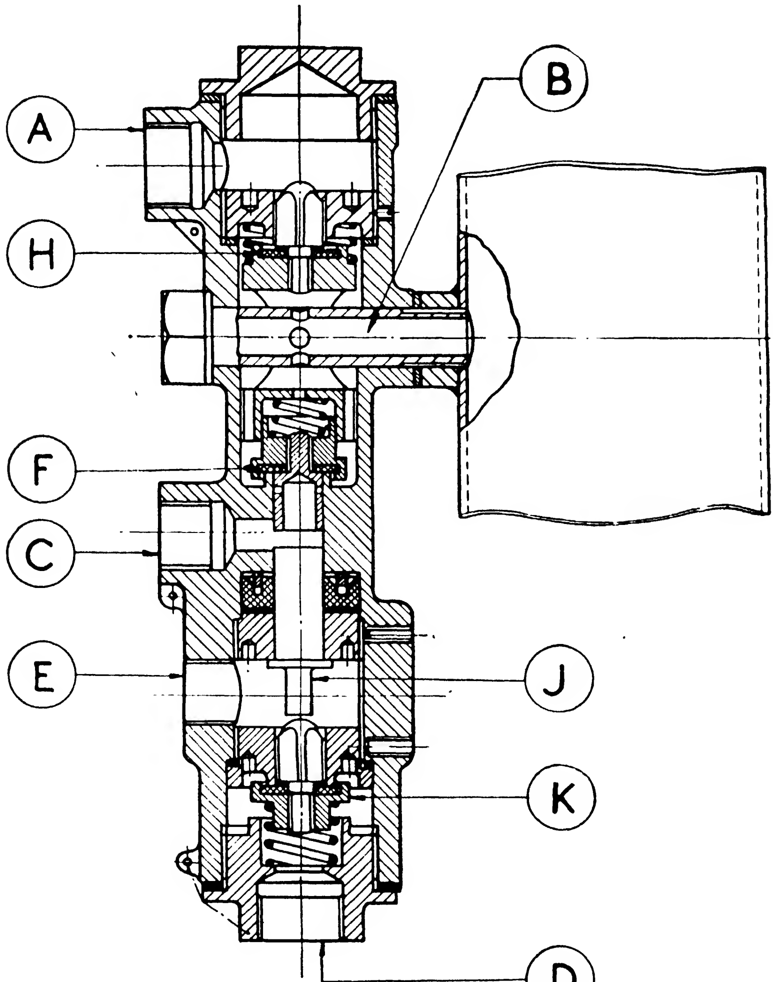



FIG. 60. EMERGENCY AIR RELEASE VALVE

that when the undercarriage is to be extended by means of the compressed air the normal oil supply pipe from the control box must be blanked off to prevent the air escaping up this line, and simultaneously a port must be opened to allow the air to go into the jack.

In addition, it is necessary to open up the return pipe line from the other

side of the piston direct to atmosphere in order to allow the jack piston to move.

This valve is shown at (*D*) in Fig. 59.

It will be obvious that any number of jacks (for example, two main undercarriage jacks and one tail wheel jack) may, by this means, be all operated from one air storage supply. Fig. 60 shows a section of one of these air release valves.

During normal operation of the jacks by hydraulic means the oil supply from the pump is fed in through connection (*A*) and out of connection (*B*) to the jack. Connection (*C*) is coupled to the air storage bottle and connection (*D*) is coupled to the main feed line to the opposite end

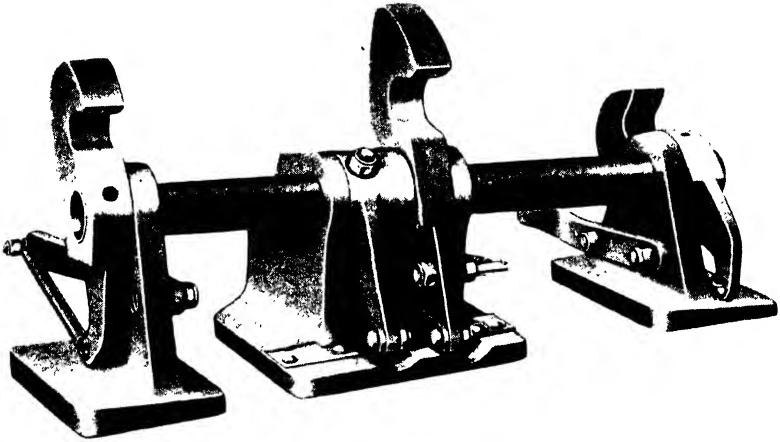


FIG. 61. LATCH LOCKS

of the jack. Connection (*E*) usually carries a short pipe which communicates to atmosphere.

This valve is entirely automatic in action, for when compressed air is admitted through connection (*C*) the valve (*F*) is forced off its seat, allowing air to escape through connection (*B*), and at the same time valve (*H*) is held down on its seat, thus preventing air from going into the pipe lines through connection (*A*). Simultaneously, the small plunger (*J*) is forced along the valve in the opposite direction. In doing so it lifts valve (*K*) off its seat and allows oil from the other side of the piston to escape into the atmosphere through connection (*E*).

## 15. UNDERCARRIAGE LOCKS

When hydraulic actuation of the undercarriage is employed it is a simple matter to operate the locks hydraulically and two methods of carrying out this operation will be described.

The first is illustrated in Fig. 61 which depicts latch locks mounted on some rigid portion of the aircraft structure and having "latches" which engage with a pin or pins attached to one of the moving members of the undercarriage.

The illustration shows a group of three latches, and in this particular assembly the two outer latches engage with pins attached to the rear folding struts or radius rods when the undercarriage is fully extended,

whilst the centre latch is arranged to pick up a pin mounted on the compression leg when this is in the retracted position.

Normally these latches are held in engagement with their pins by springs in such a manner that, when the pins move through their paths of travel, they strike the cam-shaped faces of the latches and force these back until such time as the pins come into line with the latch slots, then the springs cause the latches to snap into position over the pins. The method of releasing these locks will be readily understood by referring to Fig. 62.

It will be seen that the latches are connected to pistons working in small hydraulic cylinders and, if the "Up" lock cylinder is coupled by a

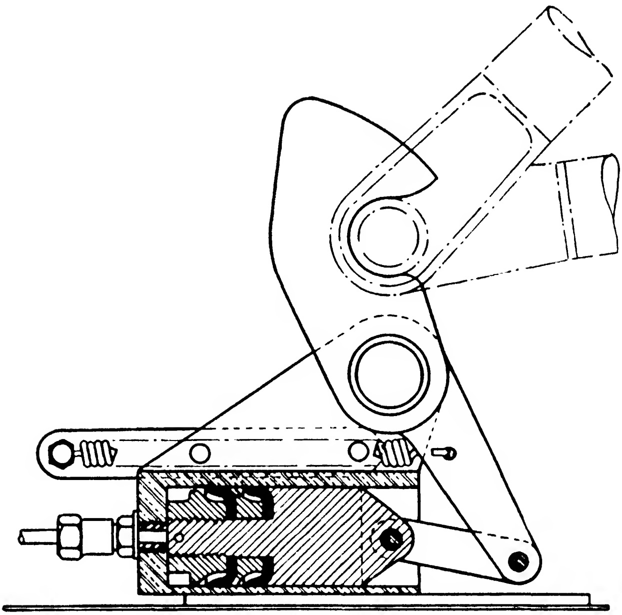


FIG. 62. UNDERCARRIAGE LATCH LOCK

pipe line to that side of the system which is under pressure when the undercarriage is being lowered, obviously the piston will move forward under this pressure and release the latch from engagement with its pin. Similarly, of course, the "Down" lock is coupled to the side of the piping system which is under pressure when the undercarriage is being raised.

Fig. 63 shows another method of operating latch locks. In this lay-out the latches are held in engagement with their pins by means of springs as in the previous type, but they are released in a different manner, i.e. by the initial movement of the piston rod in the main retracting jack.

It will be seen that the link connecting the piston rod to one half of the breaking member of the undercarriage is provided with a pin engaging in a slotted hole in the breaking member.

This slotted hole allows the link to move through a certain portion of its travel before it commences to actuate the breaking member. During this "free travel" of the link the pin in the link is in contact with one

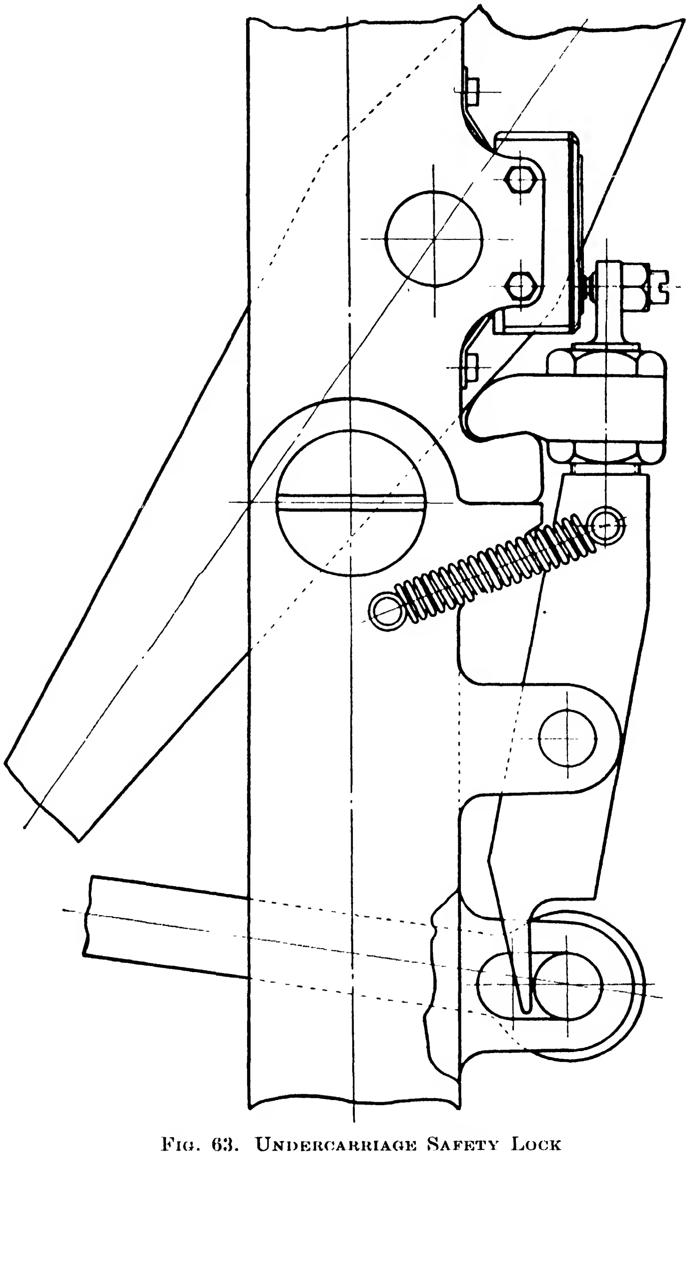
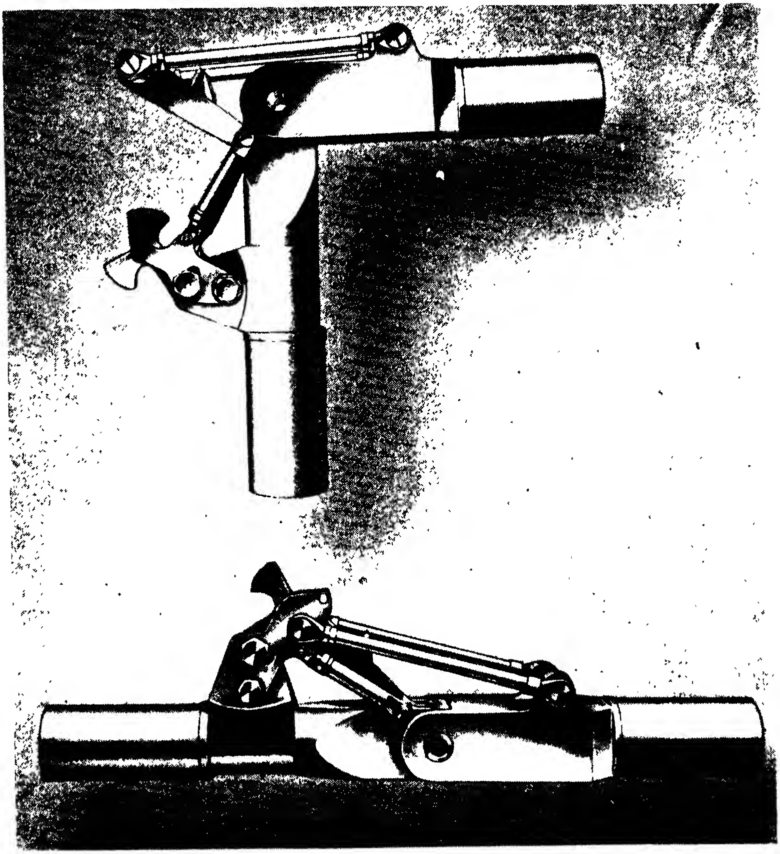


FIG. 63. UNDERCARRIAGE SAFETY LOCK

end of a lever which is extended beyond its fulcrum to form a latch which engages with a projection on the other half of the breaking member.

The latch thus forms a definite tie between the two portions.

In addition, this latch is arranged in such a manner that when it is fully engaged in the locked position, it actuates a switch which closes an



FIGS. 64 AND 65. KNUCKLE JOINT WITH "UP" AND "DOWN" LOCKS (OPEN); KNUCKLE JOINT WITH "UP" AND "DOWN" LOCKS (CLOSED)

electrical circuit to operate signal lights, thus indicating to the pilot that the undercarriage is in the safe position for landing.

Figs. 64 and 65 illustrate a knuckle joint for a retracting strut incorporating locks for the "Up" and "Down" positions, operated by free travel of the undercarriage jack.

## Warning and Indicating Devices

The usual system incorporates signal lights and an electrical buzzer. When the undercarriage is being retracted, red lights are illuminated and

they remain so until the undercarriage is again extended and fully locked home, when the red lights disappear and the green ones become illuminated. The electrical switches are operated by the locks. If the pilot closes his throttle before the green lights appear, the warning buzzer comes into action, a switch is incorporated in the throttle control for this purpose.

Dials to show the position of the trailing edge flaps are also used. The pointer being operated electrically and controlled by a potentiometer, the sliding contact of which is mechanically linked to the flap.

TRACING TROUBLES

| *Defect* | *Possible Causes* | *Remedy* |
|---|---|---|
| Jack fails to operate, or operates slowly | (*a*) Insufficient oil | Top up reservoir with oil |
| | (*b*) Defective pump | Test pump as per instruction No. 1 |
| | (*c*) Defective control valve | Test valve as per instruction No. 2 |
| | (*d*) Defective relief valve | Test valve as per instruction No. 3 |
| | (*e*) Defective cut-out | Test cut-out as per instruction No. 4 |
| | (*f*) Defective jack | Test jack as per instruction No. 5 |
| | (*g*) Air in pipe system | Bleed system as per instruction No. 6 |
| Automatic cut-out cuts in and out repeatedly | (*h*) Leaking control valve | Test control valve as per instruction No. 2 |
| | (*i*) Obstruction in pipe line | |
| | (*j*) Cut-out incorrectly adjusted | Test cut-out as per instruction No. 4 |
| Cut-out fails to operate at end of jack travel | (*k*) Dirty filter causing heavy back pressure | Dismantle and clean filter |
| | (*l*) Defective jack piston | Test jack piston as per instruction No. 5 |
| Jack operates, but slowly returns to original position | (*m*) Defective control valve | Test control valve as per instruction No. 2 |
| | (*n*) Leaking cut-out | Test cut-out as per instruction No. 4 |

## 16. METHODS OF TESTING UNITS

### Instruction No. 1—Hand Pumps

Disconnect outlet pipe and blank off outlet connection on pump by means of a blind and union nut. This may be accomplished by inserting a washer of fibre or metal in an ordinary A.G.S. union nut, or alternatively by placing a steel ball in the end of the union body and holding it in position by the nut.

If the pump is in order it will not be possible to operate the pump handle, as sufficient back pressure will be built up to prevent any movement of the handle.

If it is possible to move the handle the fault is due to either leaking valves or a defective piston.

Examine the valves to discover if any foreign matter is preventing the balls from seating properly. If the valve seats are scored or show traces of "hammering" it is usually sufficient to drop the ball on its seat and give a sharp blow to the ball by means of a hammer and suitable punch.

If the valves are in order, return to makers for examination.

### Instruction No. 2—Control Valves

Control valves can be tested in the following manner: Disconnect both pipe lines leading to the jack and blank off one of the jack connections on the valve body in the manner previously explained in the notes for testing pumps.

Set the control valve handle so that the blanked off connection would be the feed to the jack. Operate the hand pump and watch the open connection on the valve to see if the oil escapes.

If the valve is in order, back pressure will be built up preventing operation of the pump handle. If, however, oil escapes through the open connection, return to makers.

This test should be carried out, blanking off each jack connection in turn.

### Instruction No. 3—Relief Valves

Insert a pressure gauge in the pipe line between the hand pump and the relief valve and disconnect the blow-off pipe from the valve.

Operate the hand pump very slowly and check that oil escapes from the valve only when the correct pressure has been built up. The correct operating pressure is stamped on all relief valves.

A screwed adjustment is usually provided for the relief valve spring and this will enable resetting to be carried out without any trouble.

### Instruction No. 4—Automatic Cut-out

Tests to be carried out by means of a hand pump. Connect hand pump to inlet connection (*A*) see Fig. 56, and connect a pressure gauge to feed connection (*B*). Disconnect pipe from by-pass connection (*G*). Operate hand pump and check that when "cut-out" pressure is registered on gauge, say 800 lb. per sq. in., by-pass valve should open and allow oil to flow from connection (*G*). Pressure registered on gauge should be maintained by "cut-out." If the gauge reading shows a tendency to drop, return sub-component to makers.

### Instruction No. 5—Jacks

Disconnect the pipe from one end of the jack and pump oil through the opposite connection until the piston completes its travel. Continue pumping and watch the open connection for escape of oil. If the jack piston is in order, no further oil will escape from the open connection after completion of travel, but if oil continues to flow from this connection a defective piston is indicated.

### Instruction No. 6—Bleeding System of Air

Ensure that the oil reservoir is filled. If jacks are fitted with bleeder screws, slacken screws at one end of the jacks and pump oil in at the opposite end until the pistons have completed their travel, then close bleeder screws and open those at opposite ends of jack, and operate jacks in reverse direction.

If this procedure is carried out several times, all air in the system will be eliminated. If the jacks are not provided with bleeder screws, pump oil in through one connection and slightly slacken off the union nuts on the pipe connection at the opposite ends of jack to allow air to escape; when "solid" oil emerges from the loosened connection, tighten the union nuts, and lock with wire. Care should be taken to ensure that bleeder screws and pipe couplings are locked after bleeding has been carried out.

## 17. INSTALLATION NOTES

1. All pipes should be cleaned internally as thoroughly as possible after the ends have been belled. Trouble can arise as the result of metal fillings being left in the pipes after cutting the ends.

2. Take care to ensure that olives in pipe couplings are correctly aligned. A slightly crossed olive can cause a considerable rise in operating pressure due to the local restriction.

3. When fitting jacks always pump the piston to the end of its travel and then adjust the screwed end of the piston rod before coupling to the operated unit. If this procedure is not carried out the travel of the piston will be limited by some part of the aircraft structure and very heavy loads will be set up.

CHAPTER IV

# SEAPLANES AND FLYING BOATS

## 18. ORDER OF ERECTION (FLYING BOATS)

Prior to the erection of the component parts of the aircraft, the hull, supported in its cradle, is adjusted to rigging position. The order of erection adopted by manufacturers is as follows—

1. Hull adjusted to rigging position.
2. Tail unit erected on ground and lifted into position.
3. Bottom centre plane attached and engine mountings (with oil tanks) assembled.
4. Petrol tanks installed in top centre plane, and top centre plane, with centre section struts, fitted.
5. Engines installed.
6. Top outer planes erected with ailerons in position.
7. Outer interplane struts attached and bottom outer planes, with ailerons, erected.
8. Interplane struts, aileron struts and bracing wires connected up.
9. Wing tip floats fitted.
10. Alternatively the complete superstructure can be assembled on suitable trestles and lifted as a unit on to the hull.

## 19. RIGGING

**Levelling Boards**

A complete set of straight-edges, incidence and dihedral boards for the rigging are usually supplied by the manufacturers. (The incidence and

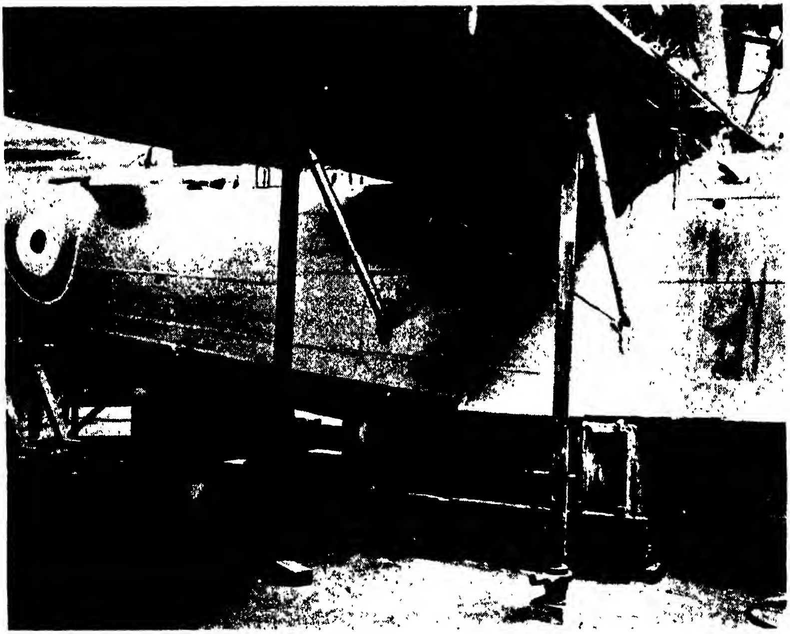


Fig. 66 Hull in Cradle and Props under Plane Chocking Blocks

dihedral boards are illustrated and the method of use shown in Figs. 6 and 7, Chapter I). If the boards are not available the aircraft can, of course, be rigged in the usual manner by measuring the angles with a straight-edge and inclinometer.

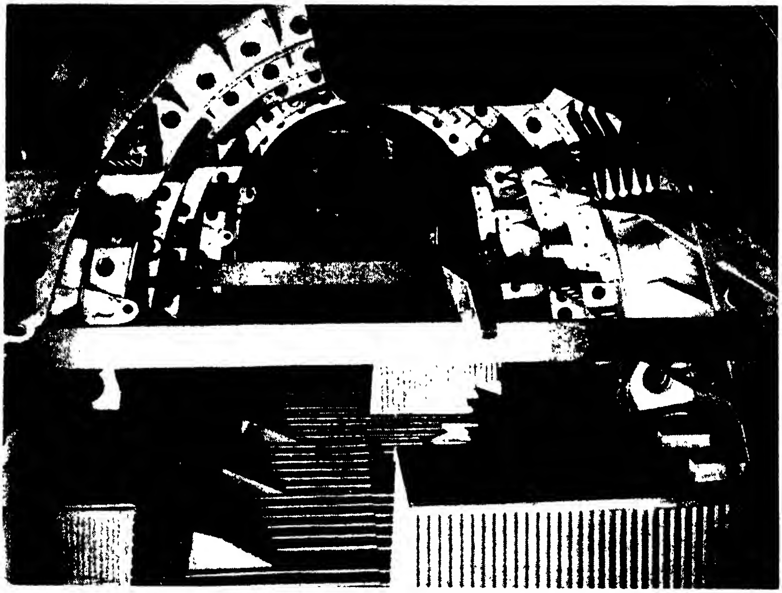


FIG. 67. PERMANENT LEVELLING BLOCKS (SHOWING STRAIGHT-EDGES IN HULL)

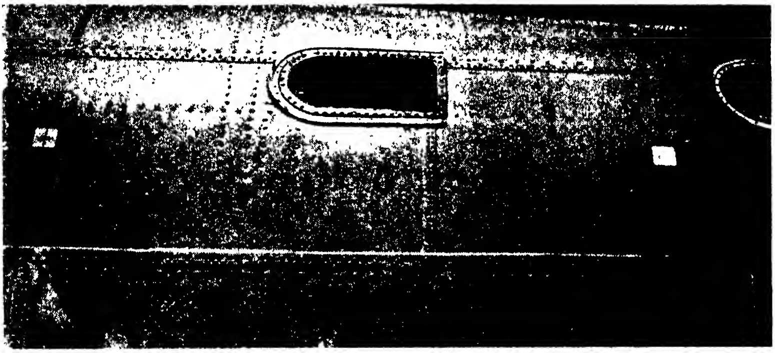


FIG. 68. DATUM-MARK PLATES ON OUTSIDE OF HULL

## Rigging Position

The construction of the hull does not allow any adjustment or truing up. The hull is placed in position on its supporting cradle and the latter adjusted by means of suitable wood packing blocks and wedges (Fig. 66) until the straight-edges are horizontal laterally when placed inside of the hull on the permanent levelling blocks, positioned as indicated in Fig. 67,

and longitudinally either by level and straight-edge along the datum lines (see Fig. 68) or internally by bridging straight-edges on the two lateral stations by a straight-edge fore and aft.

### Assembling the Tail Unit

The tail unit should be placed on felt-covered boards arranged to give adequate support to the under-surface; then the fins, rudders, inter-rudder struts, elevators, and control connecting rods are assembled. The complete unit can then be lifted into position, and attachment made to the hinge fittings on the hull and the main spindle of the adjusting gear. The struts and auxiliary stays from the hull to the tail plane front spars, and the struts from the lower end of the adjusting gear spindle to the rear spar are then fitted, and the complete unit trued up. The lower (hull) ends of the tail plane struts are usually provided with adjustable sockets which are secured to the lug plate fittings on the hull and tail adjusting gear. Short straight-edges, laid along the spars on either side of the central fin, should be horizontal when the hull is in rigging position. If necessary, adjust the struts to secure this condition.

It is sometimes found that alteration of the length of the tail plane struts produces slight local distortion of the stern of the hull, with consequent binding of the rudder and elevator transverse torque shafts. Particular note must be taken, after erection of the tail unit, that these shafts are quite free to rotate.

### Assembling and Rigging the Centre Section

The centre section may be assembled in two ways; either by erecting the bottom and top planes separately, or by assembling the whole unit and lifting it on to the hull. Where facilities exist, the latter is the best and the most convenient method.

When the planes are to be erected separately, the bottom centre plane is lifted on to the hull and the front and rear spar attachments completed. The front and rear support struts from the hull (the upper ends of which are adjustable) together with the incidence bracing are then attached, the plane being supported at the ends meanwhile. The bottom plane should then be tested for horizontal level, using the blocks provided for that purpose. The incidence of the plane should now be checked. If necessary slight adjustment for incidence can be made by varying the length of the supporting struts. At this stage it is advisable to test the bottom plane for squareness to the centre line of the hull. This is checked by measuring the distance of a point on each end of the front spar from a point at the nose and on the centre line of the hull; these distances should be equal. If any adjustment is necessary it can be effected by means of the under centre section bracing. In some types of aircraft which have built-in bottom centre sections as an integral part of the hull, no provision is made for the adjustment of the lower centre section after the hull is completely plated.

The top centre plane may now be erected. The plane is lifted into position with all the interplane struts fitted. When completely erected, the stagger, if any, of the two planes must be checked by dropping plumb lines from the leading edge of the top centre plane (see Fig. 8). Care must be taken that all struts are fitted in the correct position, as some may have dead length struts, and some adjustable screwed sockets in the lower ends.

This screwed type of socket is a standard one for adjustable struts which are structural members of the aircraft. In altering the length of any of these, care must be taken to ensure that the male portion of the

socket is not screwed out so far that it cannot be felt when a wire is inserted in the inspection hole drilled in the strut end, as otherwise the number of threads of the socket engaged in the strut will be insufficient for strength.

Where it is possible to lift the complete centre section as a unit on to the hull, the following procedure should be adopted. Raise the bottom centre plane on trestles, suitably padded and preferably set to the correct incidence, and then assemble on it the top plane (with petrol tanks) interplane struts, incidence bracing wires and engine mounting. Completely true up the centre section. Lift as a unit on to the hull and complete the attachments. Tests can then be made for horizontal level and incidence of the bottom plane, stagger if required, and squareness of the centre section with the hull.

### Attaching and Truing Up Outer Main Planes

Where only one pair of interplane struts is used for each outer section, it is not possible to "box up" the outer planes on the ground and hoist into position. The top planes, with ailerons held fast in neutral position by top and bottom battens, secured by bolts and wing nuts through the space between wing and ailerons, are erected first, and supported by slings, whilst all the interplane struts are attached and both bottom planes erected. The struts are then attached to the bottom planes and the front and rear landing wires inserted. As a precaution an extra support should be arranged under the engine mounting on the side of the first bottom plane erected, to take the weight and thus counteract any tendency to disturb the hull in its cradle. The incidence and flying wires are then fitted and all supports removed. Lastly, the interplane bracing is trued up until the correct settings are obtained.

### Assembling the Wing Tip Floats

The float struts should be fitted to the floats before attaching to the planes. Attach the float struts to their respective fittings on the front and rear spars and the bottom outer planes, then fit the incidence and bracing wires. When correctly erected the float struts should be at right angles to the undersurface of the plane. All incidence and bracing wire pin centres must be trammelled for equal measurement.

### Alternative Method of Erecting Complete Superstructure

Where suitable lifting tackle is available the complete superstructure, centre section, outer planes, interplane struts, petrol tanks, engine mountings, engines, and bracing wires can be assembled on the ground and lifted into position on the hull. If the superstructure is assembled on suitable trestles the wing floats can also be attached, but if assembly is carried out on the ground, or on low trestles, the floats must, of course, be attached subsequent to erection of the superstructure on the hull.

### Check Rigging as Follows—

1. Incidence throughout.
2. Dihedral of top planes.
3. Dihedral of bottom planes.
4. Stagger and sweepback on centre section, if any.
5. Stagger and sweepback on outer main planes, if any.
6. Different dihedral of the top and bottom outer planes produces a backward sweepback of the bottom plane, compared with the top plane, measured at the outer struts.
7. Engine mounting for alignment.
8. Tail plane incidence with adjustment each way from normal position.

**Final Check**

The usual final check measurements for symmetry of the complete aircraft should be made.

These should include the following—

1. Sternpost to foot of front outer interplane struts.
2. Nose of hull to foot of front outer interplane struts.
3. Outer tips of tail plane front spar to centre line of hull just aft of the trailing edge of bottom centre plane, also to foot of front outer interplane struts.

**Rigging of Float Undercarriage**

The aircraft should be set up with fore and aft and transverse datum lines horizontal.

The longitudinal centre lines of each float must lie truly parallel with

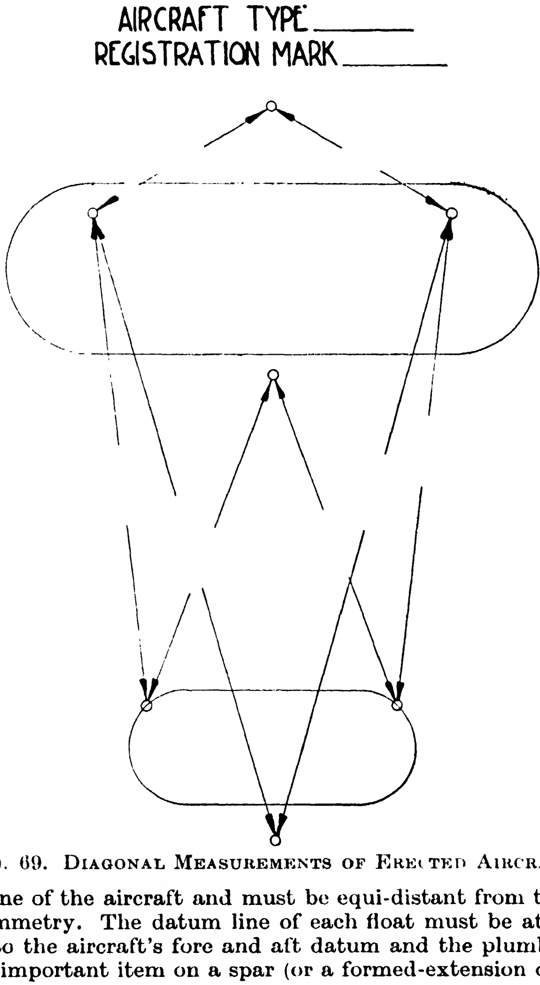



FIG. 69. DIAGONAL MEASUREMENTS OF ERECTED AIRCRAFT

the centre line of the aircraft and must be equi-distant from the aircraft's plane of symmetry. The datum line of each float must be at the correct inclination to the aircraft's fore and aft datum and the plumbed distance between an important item on a spar (or a formed-extension of the points

of attachment of the undercarriage to the fuselage) to a common point on each float must be equal.

The fore and aft horizontal distances between common points on each float and key position on the aircraft must be equal. The distance between a common point towards the bow of each float and a common point towards the stern of the other should be equal.

The individual floats should be checked to see that the dorsal or the centre of the top surface is plumb over the keel or centre of the planing bottom.

The particulars should be entered in a form similar to Fig. 69.

## Water Rudders

Water rudders are sometimes provided for seaplanes, being usually operated by the rudder bar and situated on float seaplanes at the aft end

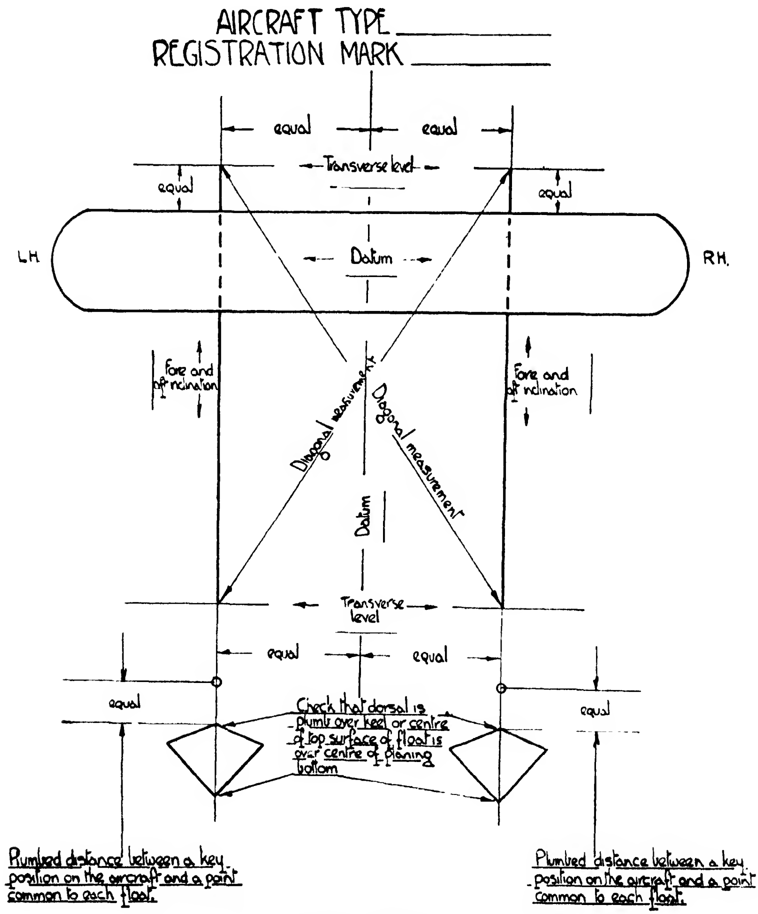



FIG. 70 SEAPLANE MAIN FLOAT RIGGING DIAGRAM

of the floats, in a similar position to that occupied by a normal ship's rudder. Water rudders are seldom used for boat seaplanes, mainly because all the control normally required is obtained from the engines, of which there are usually two or more. Water rudders are a normal part of amphibian aircraft.

## 20. GENERAL MAINTENANCE AND MINOR REPAIRS OF HULLS AND/OR FLOATS

### Repairs of Hull and Floats

The treatment of a particular repair is very largely at the discretion of the repairer, and these notes are intended only as a guide. Every effort should be made to restore the damaged parts as nearly as possible to their original strength and condition, and the methods employed in building must follow closely the directions in manufacturers' handbooks.

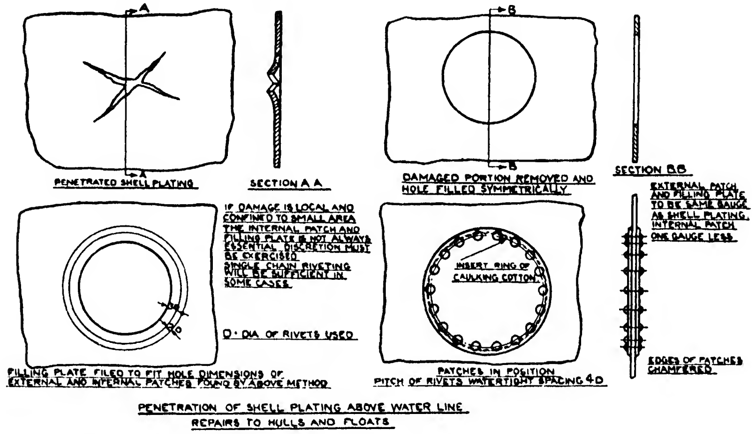



FIG. 71. REPAIRS TO HULLS AND FLOATS ABOVE WATERLINE

When repairs are carried out the plating, rivets, etc., must be to the same specification as the material being replaced; this is very important where the hull and/or floats are constructed of stainless steel, as electrolytic action takes place between various stainless steels. The size and spacing of the rivets should be the same as that found in similar parts of the structure. Patches must be riveted round the edges with the size and pitch of rivets used in the plate being patched. Rivet holes must be drilled, and the patch carefully closed to the plate with bolts before riveting is commenced. Rivets are best removed by cutting off the heads with a small cold chisel and light hammer and punching out the shank. Where the plating is perforated the jagged edges should be "faired up" or cut away, preferably to a square, oblong or circular shape, and a patch of similar (but, of course, larger) shape fitted and riveted outside (see Fig. 71).

If the repair is on a part of the structure with a pronounced curvature, the patch must be curved or beaten to shape so that it goes into position without being forced. The rivets must not be worked in consecutive order, but at intervals, otherwise the material will stretch and the rivet holes

(Figs. 71, 72, and 73 from *A.P.* 1147, by kind permission of the Controller, H.M.S.O.)

will not coincide. Where a very quick repair is necessary to under-water plating of a boat there is no need to cut out the damaged part. The piece used for patching must be large enough to lap over the part of the plate remaining fair. In making a quick repair, fix the patch by using small

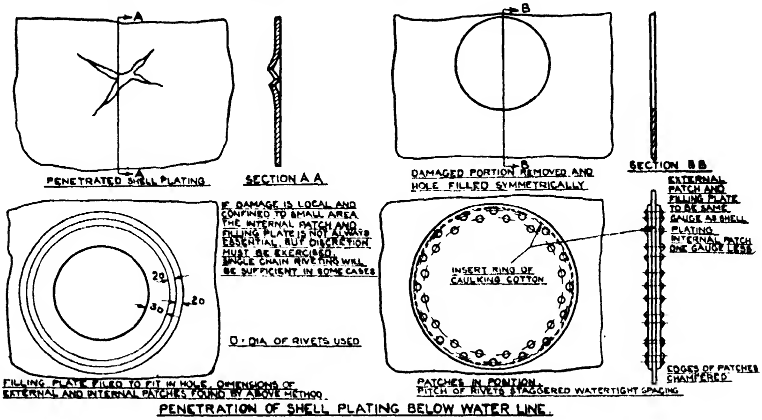



FIG. 72. REPAIRS TO HULLS AND FLOATS BELOW WATERLINE

bolts instead of rivets. Proper patching in accordance with Fig. 72 must take the place of this makeshift repair as soon as the aircraft base is reached.

## Joggled Patch

Damage at a seam or butt insufficient to warrant the removal of two whole plates would normally be repaired by a joggled patch where facilities

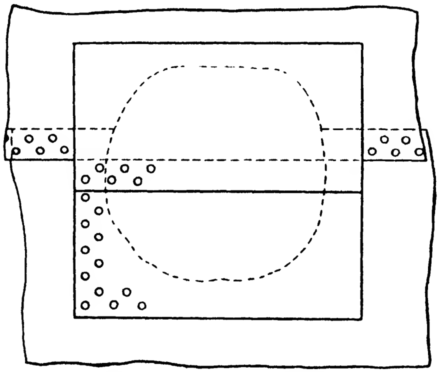


FIG. 73. JOGGLED PATCH

for joggling the plate do not exist; the difficulty in making a watertight joint where the patch crosses the leading edge of the seam may be overcome as shown in Fig. 73.

In this case two pieces are used, one butting against the edge of the outside plate and the other lapped over the first. If duralumin rivets are

used during repair work they must be heat-treated, before use, at the normalizing temperature (480–490° C.) and riveted up within 1 hour of treatment. Lower temperatures during heat treatment will render the rivets more liable to corrosion. Should a repair be carried out and no

FIG. 74. HULL PLATING BEFORE COMPLETION OF REPAIRS

approved protective covering be available, the parts should be treated with grease, until the proper coating can be applied.

Figs. 74 and 75 show a hull during and after plating repairs.

*Note*—Preservation of the structure's poise should always receive adequate attention. It will be seen that if old plates are taken off at

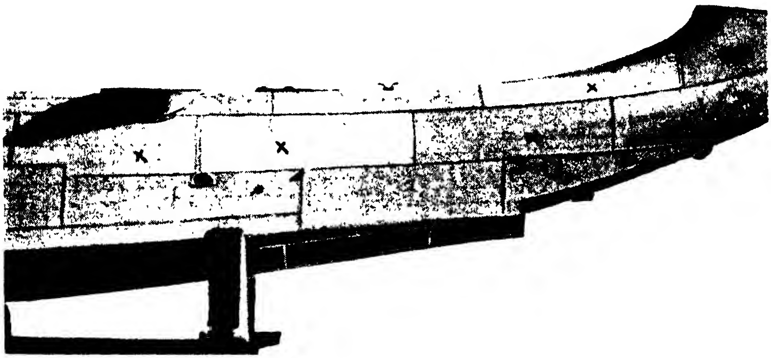


FIG. 75 SHOWING PLATING OF HULL AFTER REPAIRS

random dangerous distortion or even collapse of the structure may occur. Where more than one plate is taken off at a time, therefore, it should have been previously verified that the structure is well able to bear such a loss.

## Test for Watertightness

### HULL

After all repairs check all watertight seams; laps and collars are usually caulked with putty and white paint and cotton, but other approved

methods may be laid down in the manufacturer's handbook. A water test may be carried out as follows—

(*a*) Fill the hull with fresh water to the level of the waterline, and leave for a period of 1–1½ hours; then examine the exterior for leaks, and if any leaks are noted carefully mark same. The hull should then be emptied and the whole of the remaining plating and joints should be tested by spraying water on to all seams, etc., outside the hull, by the use of a hose pipe fitted with a small nozzle giving a fine jet of water at high pressure. Examine at the same time all joints, etc., inside the hull.

(*b*) If the hull is not filled with water, the whole of the plating and joints should be sprayed externally as already described in the latter part of paragraph (*a*).

### Floats

During repairs all watertight seams, laps, collars, and bulkheads are usually caulked with putty and white paint, and, where joggled with cotton, each compartment is finally tested separately by filling with fresh water to a depth of 10–12 in. This is allowed to stand for 5–15 minutes, the keel, bulkheads, and keelson being examined. The float is then turned on to its side and the chines examined. After securing the watertight covers, again turn the float so that all remaining joints can be tested.

### General

All laps and seams are tested by spraying the water into the other side of the lap or seam. Where leaks occur the joints should be caulked and re-tested; in the case of individual rivets leaking these should be replaced.

### Maintenance of Hulls and Floats

On no account must sea water be allowed to remain inside the hull. The interior should be carefully wiped out, particular attention being given to small crevices where water is liable to accumulate. The wing tip float inspection covers should be removed and any leakage water drained off by taking out the drain plugs. Deposits of salt must be cleaned off and wetted surfaces swabbed with fresh water and dried. Abrasions of the external and internal surfaces of hulls and floats must be first coated with an approved undercoat of paint, but this is not to be used over the whole surface on top of the original finishing coat. The deterioration of the top surface enamel will need close attention, and may necessitate the periodical application of a coat of finishing enamel. After this has been done two or three times, the whole of the paint work should be stripped and re-coated. The unlimited application of successive coats of finishing enamel would result in the cracking and flaking off of the thick coating of paint. Also, a large amount of weight would be added by each coat. The old paint should be removed by a suitable solvent such as "Nitro Mors," "Strip off," or any other approved paint remover. Light alloy hulls which are kept afloat for a long period will require special attention, i.e. when hauled up they should be scrubbed down and the bottom immediately cleaned to free weeds and barnacles, before these are allowed to dry on. This is especially necessary in the case of flying boats operating in tropical waters.

During launching and bringing the aircraft ashore it is necessary to take special precautions against damage to the hulls and floats, and for this purpose beach trolleys or a detachable chassis is used. A tail trolley is necessary in addition, when the latter form of chassis is used.

## 21. MARINE EQUIPMENT: DESCRIPTION AND MAINTENANCE

### Mooring and Towing Gear

The gear sometimes takes the form of a main control bridle, painter, and towing bridle.

The main bridle is in two lengths connected by a shackle, the ends being attached to the bow and keel of the hull. The painter connected to the bridle shackle extends some distance to a second shackle. Tow rope and side lines are attached. The side lines run aft from the towing shackle to fittings on the lower centre section, and assist to counteract yawing during towing operations. This gear should always be checked during daily inspection.

BOAT HOOK

The purpose of the boat hook is for attaching a mooring line from the aircraft to any suitable object within reach. The hook to which the mooring line is attached is provided with a spring loaded tongue to prevent it becoming disengaged from the mooring when its haft is withdrawn.

The boat hook is normally stowed inside the hull at its forward end. An additional stowage is usually provided externally adjacent to the internal stowage.

### Ground Anchors

The anchor is of a pattern similar to that used on small launches.

The flukes are detachable from the stock to enable it to be easily stowed.

The anchor, complete with approximately 6 fathoms of cable, is stowed as far forward in the hull bows as possible and is carried in order that the aircraft may be temporarily moored when a mishap has occurred or when no mooring facilities are available.

The anchor in some aircraft is cast and weighed unassisted by manpower, its cable being attached to the aircraft by belaying it on a mooring bollard situated at stem of hull. A small anchor cable drum is sometimes provided, to which the anchor cable is attached and led through a small fairlead in the hull bows. Facilities are provided on this drum for hauling or lowering the anchor.

### Sea Anchor or Drogue

The purpose of the sea anchor or drogue is for checking the forward speed and drift of the aircraft and to allow it to ride steadily in a seaway.

In shape it is usually the frustrum of a cone, although alternative shapes are sometimes employed.

It is manufactured in the best quality white canvas and is strengthened at its larger end by a wire hoop, to which the canvas body is attached. At this end a rope loop is provided to attach a cable towing line which is secured to the aircraft, the towing line's length being governed by the type of aircraft to which it is fitted.

The towing wire should be oiled, wrapped with fabric following the "lay" of the cable, stretched and served with balloon cord; this gives additional protection against salt water corrosion.

Stowage is provided for the sea anchor or drogue in an easily accessible position either on the planes or in the hull.

### Maintenance Notes

After use the drogues should be hung up and allowed to dry, and at the same time salt water should be removed from the cables and shackles before packing and placing in stowage positions. Stowages should be

checked, and when the drogues are not in use care must be taken that they are easily fastened. After renewal of cables great care must be taken

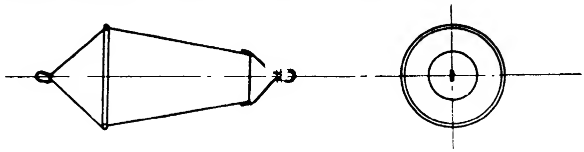


FIG 76. DETAILS OF ANCHOR

to ensure that the towing wire is attached to the bridle, as cases have occurred where the wire has been fixed to the small end, thus rendering

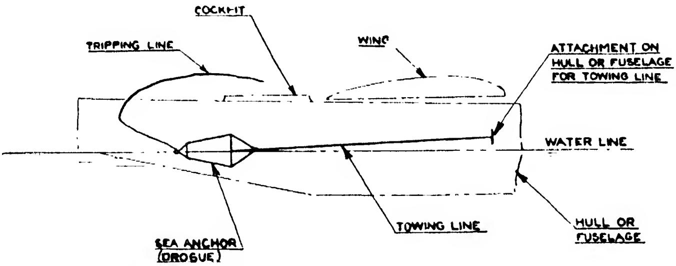



FIG. 77. RELATIVE POSITION OF ANCHOR TO AIRCRAFT WHEN IN USE

the drogues useless, which may result in serious damage or even loss of the aircraft. Therefore the complete system should always be checked.

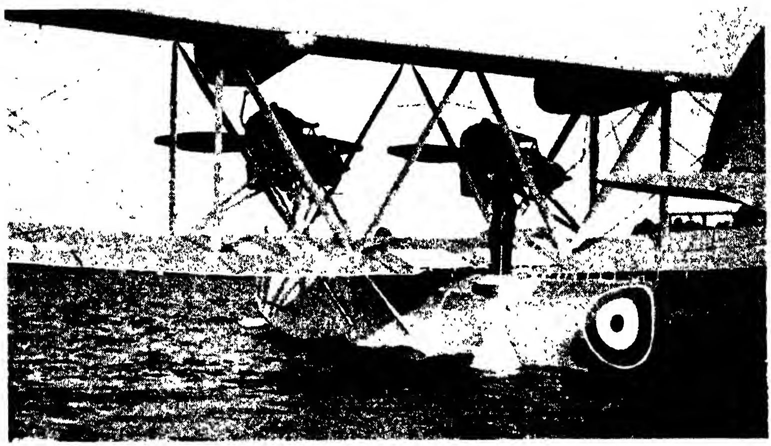


FIG. 78. HAULING DROGUE ON BOARD AFTER AIRCRAFT HAS BEEN MADE FAST AT MOORINGS

Details of the anchor are shown in Fig. 76.

The anchor position relative to the aircraft when in use (see Fig. 77).

Fig. 78 shows drogue being hauled on board after aircraft has been made fast at moorings.

### Bilge Pump

This pump as applied to aircraft is a plunger type of approximately 3 in. diameter bore and is provided with suction and discharge hoses for the purpose of clearing the hull bilges of wash.

Stowage is provided in the aircraft for the pump and hose when not in use.

The pump, which is portable, is provided with hinged footholds at its base, which are folded into the pump body when not in use.

The pump can be used at any suitable position in the hull, the suction hose being placed in the hull bilges and the discharge placed over the hull side.

# CHAPTER IV

# INSTRUMENTS

## 22. AIR SPEED INDICATORS

(Approved types: Mk. IVA and VB, Pioneer 354 and Korect)

THE air speed indicator is an instrument for use on aircraft to show the speed at which the aircraft is travelling through the air. The instrument at present used consists of a differential pressure gauge mounted on the instrument board and a pressure head fitted outside the aircraft connected to the air speed indicator by tubing.

The principle of the instrument shown in diagrammatic form in Fig. 79 is that it records the difference between the wind pressure due to the passage of the aircraft through the air and the pressure of the surrounding still air.

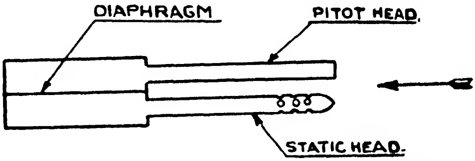



FIG. 79. AIR SPEED INDICATOR DIAGRAM

### The Pressure Gauge (A.S.I.)

Of the two most common forms of construction, one consists of an air-tight chamber divided into two compartments by means of a diaphragm. The pitot head is connected to one compartment and the static head to the other. Any change in the pressure in either compartment causes the movement of the diaphragm, which is recorded on the dial by means of a pointer. A disc with a spindle working in a guide is attached to the centre of the diaphragm; as the diaphragm moves the end of the spindle presses against a leaf spring which is deflected in proportion. The leaf spring actuates a bell crank lever, one arm of which projects through a slot in a metal plate pivoted on an axis parallel to that of the pointer spindle. At one end of this plate is a quadrant engaging a pinion on the spindle which carries the pointer. A hair spring is fitted to the pointer spindle to take up any backlash in the mechanism (see Fig. 80).

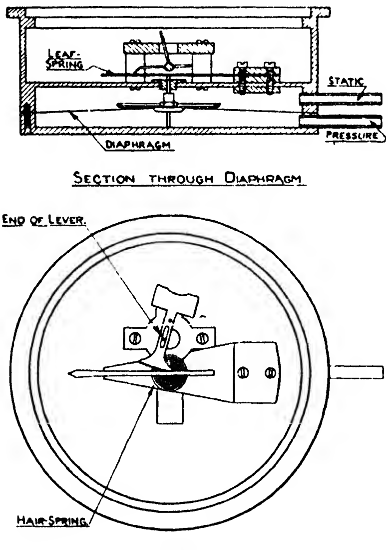



FIG. 80. DIAGRAM SHOWING CONSTRUCTION OF AIR SPEED INDICATOR GAUGE (DIAPHRAGM TYPE)

Fig. 81 shows a further type of air speed indicator which has a diaphragm box similar to an altimeter, the pressure pipe communicating with the inside of this elastic box. The pipe from the static side is led into the

(Figs. 79 and 80 from *A.P.* 1275, by kind permission of the Controller, H.M.S.O.)

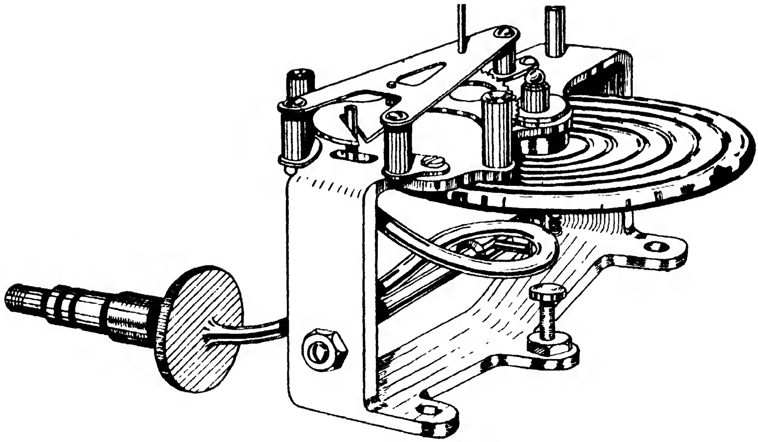


Fig. 81. Showing Construction of Air Speed Indicator (Capsule Type)

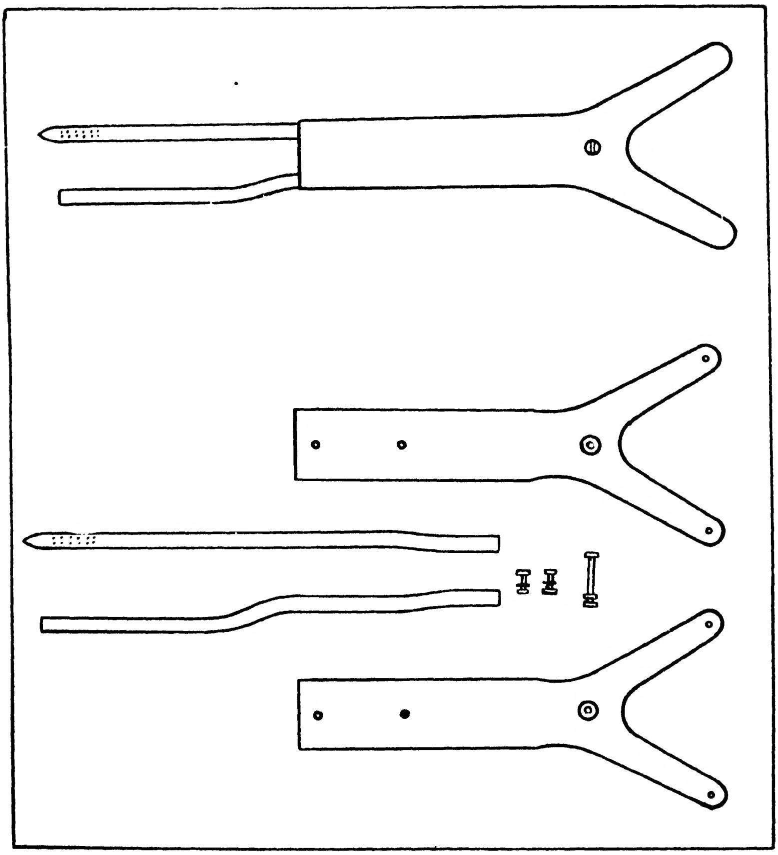


Fig. 82. Mark IVA Pressure Head

airtight case. The diaphragm box is held in a frame which also carries a transverse shaft having two short balanced arms mounted across it. The transverseshaft arms form a bell crank mechanism in which the two arms are considerably offset. One arm is coupled to the underside of the diaphragm or capsule, so that expansion or contraction of the latter results in rocking

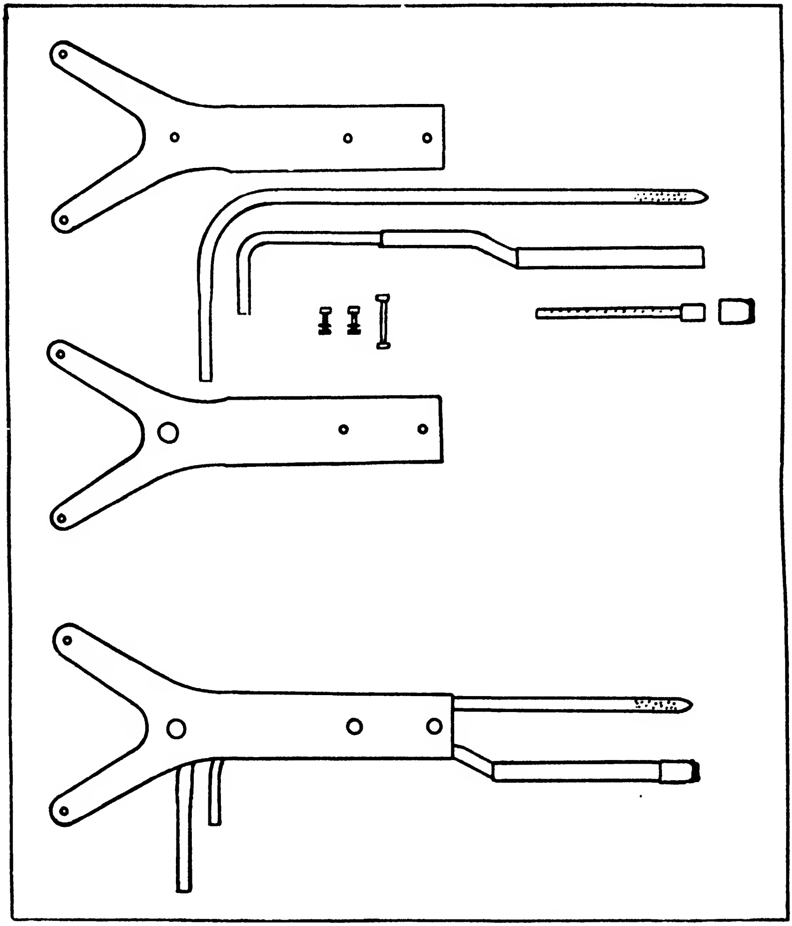


FIG. 83. MARK VA PRESSURE HEAD

the transverse shaft. The arm is cranked to pass through a hole in the top of the frame and engages in the slot of a toothed quadrant, meshing with the pinion of the pointer spindle. A hairspring is fitted to take up any backlash.

**The Pressure Head.** (Approved types: Mk. IVA and VA)

The Mk. IVA pressure head (Fig. 82) consists of a static tube with a closed pointer, the forward portion of the tube being perforated with a series of small holes. The pressure tube is open at the end.

The Mk. VA pressure head (Fig. 83) is generally the same as the IVA,

except that the pressure pipe has within it a tube closed at the back but open at the front end and drilled on its upper surface with a number of small holes which communicate with the inside of the larger pipe. The inner tube is located in the outer by a brass nipple soldered at the open end. The tube is prevented from rotating by flats on the nipple and the outer pipe. "Top" is stamped on the nipple to ensure correct assembly with perforations uppermost. A screwed nipple cap with an airtight joint fixes the inner in the outer tube.

With this pressure head the static tube is the higher placed of the two and has "top" stamped on it. The head was designed for use in tropical countries when trouble due to choking of the ordinary pressure tube by insects, etc., was met with. Care should be taken to keep the inner tube clean of any accumulations and the perforations clear. See that the word "top" is right way up on replacement.

The brass cap should be tightened with the fingers only to prevent straining the immediate installation.

### Piping

The piping from the pressure head is of light alloy on landplanes and non-corrosive material or copper on seaplanes. The tubing joints and connections are made by rubber tubing or otherwise low-pressure couplings.

### Graduation Marking of Instruments

The indicators on land aircraft are graduated in miles per hour; on seaplanes they are graduated in knots.

### Installation and Maintenance

Owing to disturbances in the air current due to the reaction of parts of the aircraft and the slipstream of the tractor airscrew, it has been found by experience that the best position for the pressure head is in front of an outer strut. On monoplanes the usual position for the pressure head is on an extension forward from the leading edge, or on a downward extension (about one-quarter of the wing chord) below the plane. The position in both cases is out towards the wing tip, beyond the influence of the airscrew slipstream.

It is important that all pressure heads should face the direction of flight. When more than one indicator is required on large aircraft the gauges are coupled up in parallel to one pressure head. To check for correct functioning let air be blown lightly down the pressure tube and hold the pressure at different stages while noting the indicator pointer. Should the pressure fall back rapidly check all the joints and pipe lines, Cases have been known where failure has been caused by corrosion eating holes through the piping.

Inspect the pressure head for damage and see that the edge of the opening of the pressure tube is smooth and round, also that the small holes in the static tube are clear. The static system should be checked by clipping a rubber tube beyond the rearmost of the small holes and applying suction instead of blowing as in the case of the pressure side. The rubber tubing should in this case be so arranged as to allow a concentric space between it and the static tube.

### Testing

The air speed indicator may be tested by connecting it up in parallel with another air speed indicator of known accuracy. Portable calibrators

(Figs. 84 and 85) are also available. These provide a portable standard against which the accuracy of air speed indicators may be checked. The scale is graduated to read direct air speeds. Air pressure is supplied to both the manometer and indicator under test, and comparison is made between the readings. The permissible tolerance is approximately ± 3 m.p.h.

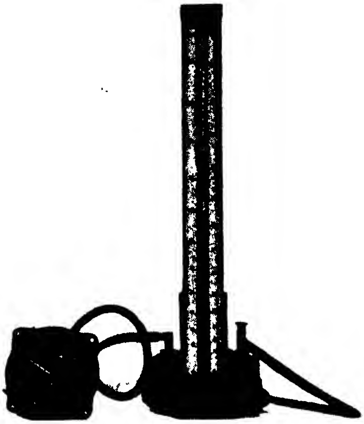


FIG. 84. AIR SPEED INDICATOR UNDER TEST (READING M.P.H.)

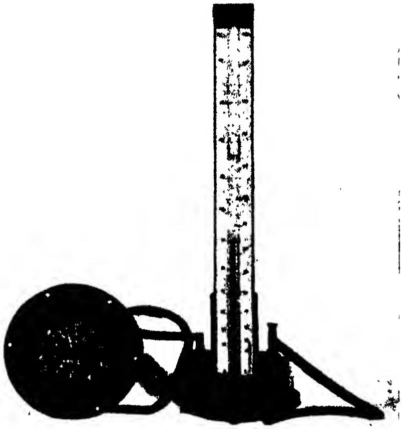


FIG. 85. AIR SPEED INDICATOR UNDER TEST (READING KNOTS)

## 23. ALTIMETER

(Approved types: Mk V, Mk VA, Mk VB)

Altimeters are instruments for indicating the height of the aircraft. These instruments are similar in construction to the aneroid barometer and measure the pressure of the atmosphere, but unlike the barometer, the dials are calibrated to read height direct. This height is, however only approximate, as the accurate determination of height is not easy, necessitating an exact knowledge of air temperatures as well as pressures. The Mk. V series instruments are calibrated in accordance with the "Isothermal Law" (i.e. the temperature of the air is assumed to be constant at all heights).

The diaphragm box is round and flat with corrugated sides, airtight and from which air has been exhausted. One side of this box is connected with the base plate, and the other to the end of the leaf spring. A change of pressure causes the diaphragm to move, and the spring moves together with the diaphragm. This small movement is magnified by means of a long connecting lever, a bell crank lever, a chain, drum, and spindle. The pointer is attached to the spindle and a hairspring is fitted to overcome any back lash (see Fig. 86).

The pointer moves over a height scale on the dial. The dial is operated by a milled knob attached to a pinion, and before each flight the milled knob should be turned to set the zero on the dial in line with the pointer. When the altimeter is installed the dial should be as near vertical as possible with the milled knob at the bottom. The instrument should be mounted so as to be unaffected by vibration.

### Testing

(Suitable apparatus: Mk. I portable type calibrator and a standard altimeter Mk. IIID.)

Altimeters are tested in a cylinder, the air being exhausted by means

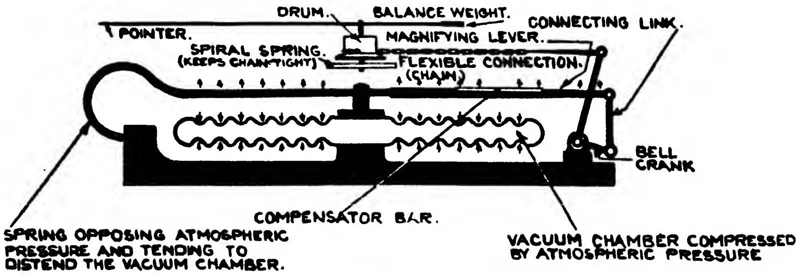



FIG. 86. ANEROID ALTIMETER

of a vacuum pump. The cylinder is fitted with guide slots, and the instrument to be tested is placed inside the chamber together with a standard altimeter Mk. IIID. Adjust the pointer on the altimeter until it corresponds to the standard gauge, then exhaust the air until the pointer on the standard gauge reads 1,000 ft., and so on at the rate of 1,000 ft. per minute, the readings on the altimeter under test being noted and compared with

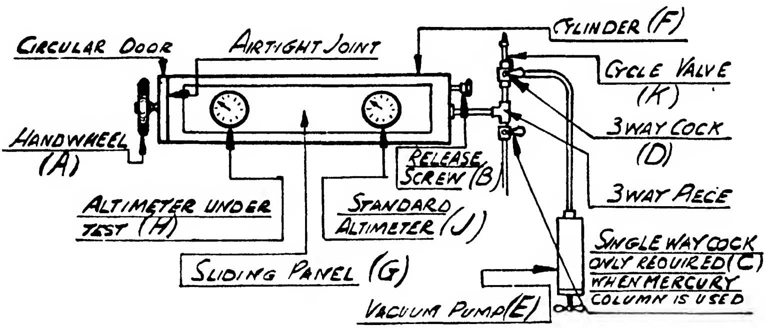



FIG. 87. DIAGRAM OF TESTING INSTALLATION FOR ANEROID ALTIMETER

the standard Mk. IIID. When this test is completed, allow air to enter the chamber through a release screw, thus increasing the pressure, and note the reading at each 1,000 ft. during descent.

The principle of the Mk. I portable type calibrator is shown in diagrammatic form in Fig. 86.

### Sequence of Operation

1. Remove circular door by releasing hand wheel (*A*).
2. Tighten up release screw (*B*).
3. Close cock (*C*).
4. Turn cock (*D*) to couple pump (*E*) to cylinder (*F*).

(Fig. 86 from A.P. 1234, by kind permission of the Controller, H.M.S.O.)

5. Draw out sliding panel (*G*) and fit altimeter (*H*) and (*J*); at the same time set altimeter (*H*) to correspond with standard (*J*).
6. Replace panel and close door by hand wheel (*A*).
7. If standard instrument is below zero, slightly exhaust cylinder (*F*) by pump (*E*).
8. If standard instrument is above zero attach small pump to cycle valve (*K*) and pump slight positive pressure into cylinder.
9. Close cock (*D*) and proceed with test already described.

## 24. TURN INDICATOR

Approved types for civil aircraft are—

| | |
|---|---|
| Reid. | Reid-Sigrist. |
| Sperry. | S. G. Brown Type E. |
| Schilovsky-Cooke. | S. G. Brown Venturi Type A. |
| Mechanism, Ltd. | Mark 1.A. |
| Pioneer No. 385. | Mark 1.B. |

A brief description follows of the latest type turn indicator—Mk. 1 (Reid and Sigrist). This indicator employs an air-driven gyroscope

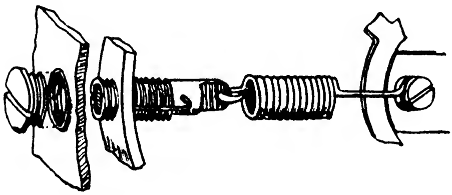


Fig. 88. Spiral Spring and Screw for Adjusting Turn Indicator Sensitivity

mounted in a horizontal gimbal ring, the axis of the gyroscope being athwart the aircraft and the axis of the gimbal ring fore and aft. When the aircraft turns, the movement corresponds to rotation of the instrument in a horizontal plane, and a precessing torque is applied to the gimbal ring to turn. The gimbal ring, being spring controlled, comes to rest in a position of equilibrium when the precessing torque balances the tension in the spring. The movement of the gimbal ring, suitably damped, is indicated by means of a pointer on the scale in the front of the instrument. A second pointer on the scale, giving a cross-level indication, is actuated through a gearing device by a pendulum, the pointer moving in the direction of tilt.

A spiral spring, the tension of which may be adjusted, is attached between the gimbal and spider (see Fig. 88) and serves to control the sensitivity of the instrument.

Access to the adjusting screw is obtained through a hole drilled in the side of the case. Insert a screwdriver into the hole and give the inside screw a slight turn anti-clockwise, according to whether less or more sensitivity is required. One complete turn in this direction is usually sufficient.

### Installation of Instrument in Aircraft

It is essential to have the instrument correctly fitted to the pilot's dashboard. The aircraft should be in the flying level position and the

top needle on the zero mark (see Fig. 89) before placing the screws in position.

Fit the venturi (see Fig. 90) in the slipstream as near the dashboard as possible, and connect to the instrument, using light alloy metal tubing

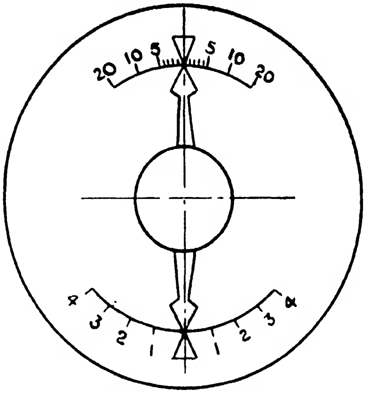



Fig. 89. Top Needle with Relation to Zero Mark, Turn Indicator

and low-pressure metal couplings, or a piece of pressure rubber tubing. Care should be taken to fit the venturi in the best position. If the aircraft is fitted with an air-cooled engine, fit on or near the exhaust pipe; on water-cooled engines the venturi can be fitted behind the radiator, so that the warmth from the engine will prevent the tube becoming frozen, no matter

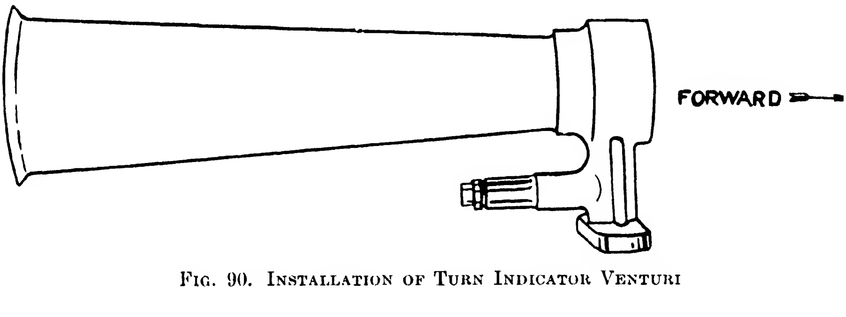



Fig. 90. Installation of Turn Indicator Venturi

at what altitude the aircraft is flown. When the venturi is in position the small end must be in front, facing the line of flight.

## The Gyro Rotor Unit (Reid and Sigrist)

The principle of the air-driven turn indicator is shown in Fig. 91.

(*a*) The position of the unit when the instrument is running normally, that is, when the aeroplane is flying a straight course.

(*b*) The position of the different components when the gyro needle is indicating a rate of turn to the left, the action being as follows—

The gyro is spun by the inlet of air through the jet and precesses clockwise on the end bearings, the amount of precession being controlled by

the spring. The needle is moved by the gearing, so that its indication is twice the angular amount of the gyro precession.

(c) The position of the unit when the gyro needle is indicating a turn to the right.

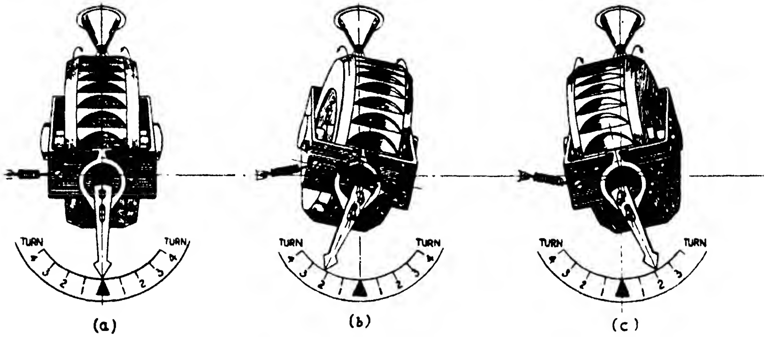



FIG. 91. TURN INDICATOR GYRO ROTOR UNIT

## Maintenance

The instrument should be examined occasionally to see that the air connection is airtight, and that the nozzle of the case is screwed up so that no leaks occur. Clean the dust cap, and remove the top cap nozzle and the double gauze filters.

To do this the three small screws in the top cap of the inlet nozzle should be removed, and the double gauze filters taken out, cleaned, and replaced. At the same time the inside of the tube should be cleaned and the neck examined to see that no dust from the engine has accumulated around it. No attempt should be made to dismantle this instrument. If a fault develops, the instrument should be returned to the makers for overhaul.

## The Directional Gyro

The directional gyro is operated by vacuum at $3\frac{1}{2}$ to 4 in. of mercury, supplied by means of a venturi tube or by an engine-driven vacuum pump. The gyro or rotor spinning about a horizontal axis at approximately 10,000 r.p.m., is universally mounted, i.e. it is supported in a gimbal ring which is free to turn about the axis on bearings in the vertical ring. The vertical ring is free to turn about the vertical axis. The circular card which is attached to the vertical ring is observed by the pilot through a rectangular opening in the front of the instrument case.

When spinning, the gyro obeys a fundamental gyroscopic principle—i.e. rigidity. Thus the rotor and gimbal ring and the card which is attached to the vertical ring remain fixed and the aeroplane moves around them. The card is observed in relation to a lubber line on the front of the instrument and is used in the same manner as a compass. The card may be set to any desired heading by means of the caging knob underneath the dial. When this knob is pushed in it engages the synchronizer pinion with the synchronizer gear. The operation of the caging mechanism which holds the gyro upright when the card is reset is as follows—

Pushing the caging knob in engages the synchronizer lever plunger which normally rests in the cone-shaped interior of the pinion, and raises the lever pins, which slide in the concentric groove of the synchronizer

ring. The action of the pins lifts the synchronizer ring, pushing up the spring plunger and raising the caging arm so that it makes contact with the bottom of the gimbal ring and holds the gyro horizontal as the card is turned to the desired heading. Pulling the caging knob out releases the caging mechanism and leaves the gyro horizontal and free.

The air jets of the nozzle, which spin the rotor, also serve to keep it upright. The air is divided into two parallel jets, each jet striking the buckets at points equidistant from the centre. If the rotor tilts, the air from the jet on one side strikes against the rim instead of against the buckets, while the air from the other jet strikes the side of the buckets, causing the rotor to return to its upright position.

## Installation

The direction indicator is mounted on the instrument board, preferably in a central position so that it is easily seen. The board or panel must be vertical in normal flight and must be at right angles to the fore-and-aft axis of the aeroplane, and special arrangements must be made to isolate the instrument from vibration exceeding 0·004 in. in amplitude.

When the instrument is fixed it must be checked by a spirit level in the fore-and-aft and the transverse direction, with the aeroplane supported in the level-flight attitude. The centres of the fixing holes should be used as reference points for the transverse level and the top surface of the case for the fore-and-aft level. The longitudinal axis of the instrument must be parallel with that of the aeroplane.

When a venturi tube is used the pipe line to the instrument should consist of $\frac{3}{8}$ in. outside diameter $\times$ 20 s.w.g. light-alloy tubing to British Standard Specification T.4, if the length does not exceed 12 ft. If the length is between 12 ft. and 25 ft. it should be $\frac{7}{16}$ in. outside diameter $\times$ 20 s.w.g. tubing of the same material. A relief valve is usually connected in the pipe line to limit the degree of vacuum, so that if sufficient is provided at low air speeds there will not be an excess applied to the instrument at high air speeds.

The coupling for the tubing is provided with the instrument. It consists of a coupling body threaded externally at one end to screw into the instrument and at the other end to take a union nut. A double-taper sleeve fitting inside the body, and the union nut to tighten on to it are also provided. The coupling body is fitted into the aperture giving the most suitable position of the pipe line, and the other apertures are closed with the plugs provided.

To make the joint the end of the tubing is cut square and the burrs removed. The tube is then passed through the union nut and the sleeve, and should bolt against the shoulder of the union body. The nut is then tightened up and the joint is complete. A rounded shoulder in the nut and a similar shoulder in the body bear on the two external tapered surfaces of the sleeve and contract it on to the tube. The tube is thus gripped and the joint sealed by the one operation of tightening the nut. It is not necessary to screw up the nut very tight. A good joint can be made if the nut is little more than finger-tight, and excessive force will damage the sleeve.

If $\frac{7}{16}$ in. tubing is used it must be joined to the $\frac{3}{8}$ in. tubing close to the instrument.

## Maintenance

The internal mechanism of the instrument should require no attention. The case is sealed and must not be opened, any faulty instrument being

returned for repair. The tubing should be inspected periodically and all joints examined. If any rubber tubing is used it should be examined for signs of damage or deterioration and must be renewed if necessary.

The air filter should be cleaned periodically. The four screws and the seal securing the plate to the bottom of the case must not be removed in any circumstances. The filter gauzes can be taken out after removing the spring ring in the recess in this plate. The discs should be brushed with benzine or petrol and should be thoroughly dried before they are replaced.

The vacuum applied to the instrument during flight may be checked by connecting a gauge to one of the apertures at the back of the case. If the value obtained is less than 3 in. or more than 5 in. of mercury the tubing and connections, and the relief valve if one is fitted, should be carefully examined for leaks or obstructions. If the tubing is sound it should be blown through with compressed air to remove any water, oil or grit that may have lodged in it. Too high a vacuum may be produced in an installation where there is no relief valve if the air intake filter is clogged.

If the instrument is to be removed from the aeroplane the gyroscope must first be caged by pressing the adjusting knob in towards the dial, and the knob should be left in this position till the gyroscope is again in operation.

The following tests should be made on an instrument after it has been ascertained that the vacuum applied is adequate, to ascertain whether it is serviceable.

The instrument should be supported in the normal position with the dial in a vertical plane, and should be run for ten minutes to attain a steady speed. The scale should then be set to zero and the instrument run for a further fifteen minutes. The reading at the end of this period should be taken and the amount of stray noted. The test should then be repeated on settings of 90°, 180°, and 270° and the stray on each setting noted. For no setting should the stray exceed 5° in the fifteen minutes' run.

After the vacuum has been applied for ten minutes to allow the rotor to reach a steady speed the vacuum should be cut off. The time taken for the rotor to come to rest after cutting off should be at least eight minutes.

## The Sperry Horizon

The gyro is mounted in the case and spins about a vertical axis. An indication from the gyro is picked up and brought around to the face of the instrument by a horizon bar which is actuated by a pin protruding from the case through a slot in the gimbal ring.

To keep the gyro upright, four pendulous vanes are suspended from the under side of the gyro housing. Each one of these vanes partially covers one of the four air ports that exhaust the air from the gyro compartment. If the gyro departs from its upright position, gravity holds the vanes vertical, and one vane closes one port while the opposite vane opens its port. The reaction of the air emitted from this open port moves the gyro anti-clockwise back to its normal position. The corrective movement, which is at right angles to the air force, is called "precession," and is characteristic of all gyroscopics. The rate at which the gyro precesses in response to the action of the pendulous vanes is so slow that the precessional forces created by the swinging of the vanes in rough air cancel one another before they have time to displace the gyro.

### Installation

The position of the instrument on a panel is not so important as the setting or alignment. The latter should be carefully proved. A period of five minutes should be allowed to lapse after the source of power has been directed on to the rotor. The instrument should read zero pitch to within $\pm$ 0·05 in. from the pitch datum, and zero roll to within $\pm \frac{1}{16}$ in. at each end of the silhouette ring when the aeroplane is in the position as for normal flight. The longitudinal and lateral axes of the instrument should therefore be aligned to those of the aeroplane to ensure the zeros or datums when the spin axis of the rotor will then be practically plumb or vertical.

It is very important when fitting the instrument to take precautionary measures against probable distortion and vibration of the case which are detrimental to the efficiency and life of the instrument.

### Maintenance

The case must not be opened, and a faulty instrument must be returned for repair. The only part of the instrument likely to need maintenance in service is the air-inlet filter.

## 25. COMPASS INSTALLATION IN AIRCRAFT, AND ADJUSTMENT

I. Inspection before installation.
II. During installation.
III. Coefficient A.
IV. Coefficient B.
V. Coefficient C.
VI. Sequence of swinging.
VII. After adjustment.

### I. Inspection Before Installation

(*a*) Inspect compass for damage in transit.

(*b*) Inspect for freedom from pivot friction. The compass should be in a level position; note the reading; by the use of a magnet deflect the compass needle through about 10°, remove the magnet and if the compass magnet system returns to its original position when the bowl is tapped with the finger the compass may be considered free from pivot friction.

(*c*) Inspect for freedom from discoloration of the card, bowl, liquid, or window. The compass must be sufficiently clear to enable the pilot to read under normal flying conditions.

(*d*) Inspect the anti-vibrational devices; moving parts must be inspected for condition.

(*e*) See that the bowl is completely filled with approved liquid, and if even small bubbles appear add more of the approved liquid until all bubbles disappear.

### II. During Installation

(*a*) The compass should be handled carefully and must not be subjected to shocks.

(*b*) Mountings should be of non-magnetic material and securing screws should also be of non-ferrous or other non-magnetic metal.

(*c*) With the aircraft in rigging position the compass should be horizontal (or vertical according to type).

(*d*) The lubber line must be forward and be parallel with the fore and aft centre line of the aircraft.

(*e*) The corrector box must be fitted below the centre of the compass with one set of magnet holes fore and aft.

(*f*) All removable and fixed equipment must be in the correct position before swinging the aircraft for compass adjustment.

No. 1 Corrector

The No. 1 Corrector is used with the P4 and P6 compasses to correct

for coefficients *B* and *C* of the deviation. It provides an adjustable magnetic moment in the fore-and-aft direction and another athwartships.

It consists of two pairs of magnets disposed horizontally one above the other in a small cylindrical case, and each magnet is capable of rotation in the horizontal plane. In the normal setting the magnets of each pair are parallel to each other and close together, and the N. pole of one is adjacent to the S. pole of the other. In this position the magnetic fields neutralize each other and the compass is not deflected.

The magnets of one pair normally lie fore-and-aft and of the other pair athwartships. The two magnets of each pair are connected by gearing to an adjusting head in such a way that if the head is turned, one magnet will turn in one direction and the other in the other direction. A resultant magnetic moment will then be produced at the compass in a direction at right angles to the original directions of the magnets, and will be of a strength depending on the angle through which the magnets are turned.

The four magnets must necessarily be at different distances from the compass, and if their magnetic moments were all the same the resultant field at the compass, even at the mid-setting of the corrector, would not be zero. The magnetic moments of the magnets are therefore made so that the field strength each produces at the compass is approximately the same. The lowest magnet is thus the strongest and the highest the weakest. It is therefore essential to fit the corrector the right way up, that is with the mounting lugs towards the compass.

The corrector is adjusted by means of the key. The neutral position of the magnets is not marked but must be found by turning the adjusting head to the two extreme positions and determining the mid-position.

### Analysis of Deviation

## III. Coefficient A

All the iron and steel parts and equipment of an aircraft are magnetic to some extent, and each individual part in the neighbourhood of a compass tends to cause deviation. It would be impossible to compensate separately for the effect of each individual part, but fortunately this is not necessary. All the possible magnetic effects in an aircraft can be resolved into five distinct types which are called the approximate coefficients, and are distinguished by the five capital letters *A* to *E*. The deviation coefficients *D* and *E* will be ignored here as no provision is made in any modern compass for corrections. It is necessary to know how to calculate the coefficients and how to correct for them. The necessary rules are given below, the calculations being based on the following deviation table—

| Magnet | Compass | Deviation |
|---|---|---|
| N. (0°) . . . . | 350° | + 10° (E.) |
| N.E. (45°) . . . . | 39° | + 6° (E.) |
| E. (90°) . . . . | 91° | − 1° (W.) |
| S.E. (135°) . . . . | 140° | − 5° (W.) |
| S. (180°) . . . . | 186° | − 6° (W.) |
| S.W. (225°) . . . . | 228° | − 3° (W.) |
| W. (270°) . . . . | 261° | + 9° (E.) |
| N.W. (315°) . . . . | 301° | + 14° (E.) |

The effect of coefficient *A* is to cause the same deviation on all courses. Coefficient *A* may be set up by—

(i) An unusual distribution of soft iron in the craft;

(ii) The incorrect mounting of the compass (lubber line slewed out of its correct position); or

(iii) The incorrect mounting of the card upon the magnet system (card error).

In the first case the coefficient is known as "real $A$" and in the other two "apparent $A$." Coefficient $A$ is calculated by the following formula

$$A = \frac{\text{Sum of 8 deviations on N. N.E. E. S.E. S. S.W. W. N.W.}}{8}$$

To calculate $A$ from the deviation given above

$$A = \frac{+10 + 6 - 1 - 5 - 6 - 3 + 9 + 14}{8} = \frac{+39 - 15}{8} = \frac{+24}{8} = +3^\circ$$

Whether $A$ be real or apparent the method of correction is the same. To correct $+A$, turn the compass bowl round clockwise. To correct $-A$, turn the compass bowl round anti-clockwise. Hence, since the value of $A$ in the example is $+3^\circ$, the method of correcting would be to loosen the bolts holding the compass, turn it 3° clockwise (reading the 3° from the compass) and then secure the instrument again.

## IV. Coefficient B

This may be considered as due to an imaginary magnet lying in the fore and aft line of the machine. The maximum effects are found on magnetic east and west.

Coefficient $B$ is obtained from the formula

$$B = \frac{\text{Deviation on east} - \text{deviation on west}}{2}$$

To calculate $B$ from the example—

$$B = \frac{-1 - 9}{2} = \frac{-10}{2} = -5^\circ$$

Notice that the sign of deviation on west is changed from + to −. The sign of a deviation must always be changed when the sign (−) precedes the deviation in the formula (algebraic subtraction). The rules for correcting $B$ are—

To correct $+B$, use fore and aft magnets with red poles forward.

To correct $-B$, use fore and aft magnets with blue poles forward.

Correction is carried out when the craft is heading east or west.

To correct for $B$ of $-5^\circ$, insert magnets in the fore and aft tubes in the corrector box, blue poles forward, until the compass reading changes by 5° as nearly as possible.

## V. Coefficient C

The effect of this is similar to that of a magnet lying athwartships in the aircraft. The maximum effects are found on magnetic north and south.

The formula for calculating coefficient $C$ is

$$C = \frac{\text{Deviation on north} - \text{deviation on south}}{2}$$

To calculate $C$ from the example

$$C = \frac{+10 + 6}{2} = \frac{+16}{2} = +8^\circ$$

The rules for correcting for coefficient $C$ are—

To correct $+C$, use athwartships magnets with red poles to starboard.

To correct $-C$, use athwartships magnets with blue poles to starboard.

The correction is carried out when the aircraft is heading north or south. The correction in the example would consist of inserting magnets in the athwartships tubes with red poles to starboard until the compass reading changed by 8°.

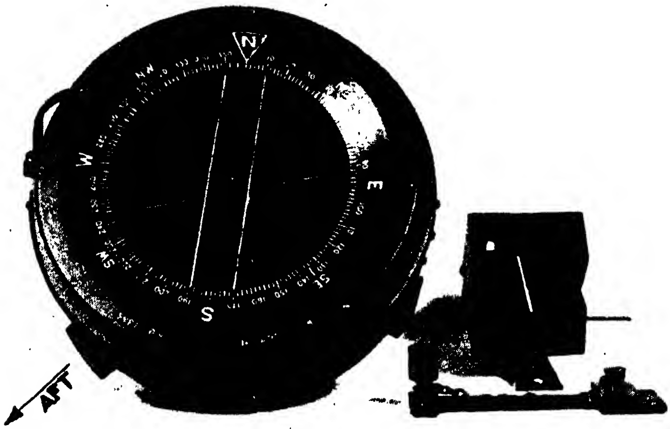



FIG. 92 P.4 COMPASS WITH CORRECTOR BOX DETACHED SHOWING MAGNETS PARTIALLY WITHDRAWN

## VI. Sequence

Adopt a definite sequence when swinging any aircraft. A sequence is given here which may be simply followed. If more than one compass is fitted in the aircraft corrections to all compasses must be made before the aircraft is moved.

(*a*) Place the aircraft on magnetic N. Align it carefully; put the aircraft and its controls in flying position. Enter the compass reading in log book.

(*b*) Place the aircraft on E. Enter compass reading.

(*c*) Place the aircraft on S. Enter compass reading.

(*d*) Calculate and correct for coefficient *C*.

Calculations of coefficients and corrections made.

To calculate coefficient *C*.

Deviation on N. = − 3°; on S. = + 5°.

Then $C = \frac{-3-5}{2} = -4°$.

To correct for coefficient *C*.

Insert magnets athwartships with blue poles to starboard until compass reading changes 4°—i.e. until compass reads 179°.

**VI. Sequence**—(*contd.*)

(*e*) Enter corrected reading on S.

(*f*) Place the aircraft on W. Enter compass reading.

(*g*) Calculate and correct for coefficient *B*.

To calculate coefficient *B*.
Deviation on E. = + 6; on W. = − 7.

Then $B = \frac{+6+7}{2} = +6\frac{1}{2}°$.

To correct for coefficient *B*. Insert magnets fore and aft with red poles forward until compass reading changes by $6\frac{1}{2}°$. Suppose the nearest to this obtainable is 6°, then compass will read 271.

(*h*) Enter correct reading on W.

(*i*) Place the aircraft on N.W. Enter corrected reading.

(*j*) Place the aircraft on N. Enter corrected reading.

(*k*) Place the aircraft on N.E. Enter corrected reading.

(*l*) Place the aircraft on E. Enter corrected reading.

(*m*) Place the aircraft on S.E. Enter corrected reading.

(*n*) Place the aircraft on S.W. Enter corrected reading.

(*o*) Calculate coefficient *A* from corrected readings and correct for it if necessary.

Calculations of coefficients and corrections made.

To calculate coefficient *A*.
Deviations on the eight cardinal and quadrantal points after correction are—
+ 1, 0, 0, 0, + 1, −1 , −1, − 1,

Then $A = \frac{+2-3}{8} = -\frac{1}{8}°$ which is too small to attempt to correct.

EXAMPLE OF PARTICULARS ON COMPASS CARD

| | |
|---|---|
| Adjustments made at | Southampton Aerodrome. |
| Date of Adjustment | 17/11/33. |
| Type of Aeroplane | "Goodflyer." |
| Registration of Aeroplane | G–OXYZ. |
| Type of Compass | P.4. |
| Number of Compass | 8135.A. |

| | First Reading | Corrected Reading | Number and Disposition of Adjusting Magnets |
|---|---|---|---|
| N. (0°) | 3 (*a*) | 359 (*j*) | 1 magnet 2/32 red to port. |
| N.E. (45°) | | 45 (*k*) | |
| E. (90°) | 84 (*b*) | 90 (*l*) | |
| S.E. (135°) | | 135 (*m*) | 2 magnets 2/32 red forward. |
| S. (180°) | 175 (*c*) | 179 (*e*) | |
| S.W. (225°) | | 226 (*n*) | |
| W. (270°) | 277 (*f*) | 271 (*h*) | |
| N.W. (315°) | | 316 (*i*) | |

Adjustment made and Deviation Card fitted by—

*Signature* JOHN BROWN, G.E., No. A, 125.
*Remarks* Compass liquid slightly discoloured.

### VII. After Adjustment of Compass

(*a*) Fasten the corrector box covers securely.

(*b*) Fill in a deviation card (both sides) for each compass in the manner shown in the above example and mount it near the appropriate compass.

### Ascertaining Deviations by Landing Compass (Landplanes)

Any aircraft can be swung as accurately by landing compass alone as by means of a swinging base (and in the case of large machines often more quickly). The aircraft should be set up in the open, at least 40 yards away from any considerable masses of iron, such as hangars, railway lines, etc., or 150 yards from an electric or W/T generating station, and the site chosen should be free from local magnetic effects.

Plumb lines should be suspended from the centre of the nose of the aircraft and the centre of the stern, and the landing compass should be set up in line with these and approximately 40 ft. in the rear of the aircraft. By sighting carefully through the slot and hair line of the landing compass on to the suspended plumb lines the correct magnetic heading of the aircraft can be read on the landing compass through the prism fitted thereto. The difference between this reading and that shown by the aircraft compass indicates the amount of error in the latter (i.e. the deviation) on any particular bearing. Successive readings are taken by swinging the aircraft about a fixed pivot point and by moving the landing compass round at a fixed radius from the same point, lining up always with the two plumb lines. It is not necessary to line up the aircraft "dead on" the desired bearing. A maximum error of 4° is permissible provided the error as shown by the bearing compass is added to or subtracted from the aircraft compass reading as necessary in order to deduce what reading the latter compass would have given if the aircraft had been aligned accurately. For example, if the aircraft compass shows 85° when the landing compass shows 88° it may be assumed that the aircraft compass would have shown 87° when the aircraft was correctly aligned on the 90° bearing. The method of correcting errors in the aircraft compass has already been dealt with.

### Swinging an Aircraft Afloat

As a general rule the compass of an aircraft should not be corrected when it is afloat, as even under the most favourable conditions the degree of accuracy easily to be obtained from swinging ashore can scarcely be obtained. It is occasionally necessary or convenient to check the deviations while the aircraft is afloat, and of the various methods two will be briefly described.

The swinging is normally carried out while the aircraft is moored to a buoy. The essential problem is to determine the correct magnetic course of the aircraft at a given moment. One method is to take bearings of a distant object, preferably by bearing compass or from a bearing plate. An object should be selected at a suitable distance and its magnetic bearing from the buoy should be determined from a chart.

As a rough guide it may be mentioned that if the selected object be 3 miles distant from the buoy and the aircraft can move round a circle of 20 yards diameter, the maximum change of bearing due to alteration of the position of the aircraft will be of the order of ¼°. Suppose the object selected be a lighthouse—$L$ in Fig. 93—and the magnetic bearing of $L$ from the buoy $B$ is 30°. Then suppose that a bearing of $L$ is found to be 34° by bearing compass from the aircraft at a moment when the course of the aircraft, by the bearing compass, is 70°. If $C$ be the bearing compass, it is seen that the direction $CL$ is given as 34° by the instrument

when actually its direction is 30°. It follows that a deviation of $-4°$ exists, and this is the deviation on a course of 70° by compass. Hence, the magnetic course of the aircraft when the bearing was taken was 66°. It should be noticed that, if $MM_1$ represent the magnetic meridian, the bearing compass measures the angle $MCL$ (plus or minus the angle of deviation), according to whether the deviation is westerly or easterly.

Considering now the use of a bearing plate, suppose $P$ in Fig. 94 represents the bearing plate, and $C$ the pilot's compass. The bearing plate must be fixed in the aircraft so that its lubber line lies in or parallel to the centre line of the aircraft, and it must be clamped with zero registering against the forward lubber line. Readings should be taken from the fore-sight of the instrument.

Suppose the bearing of $L$ is found to be 324° and simultaneously the course by compass is 70°. If $CPB$ be the centre line of the aircraft, the compass measures (inaccurately if there be any deviation) angle $MCB$.

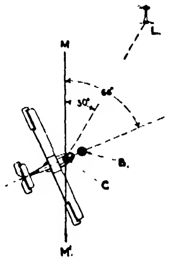



FIG. 93. SWINGING AN AIRCRAFT AFLOAT BY BEARING COMPASS

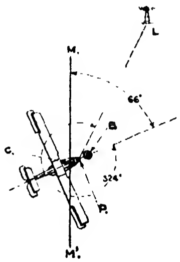



FIG. 94. SWINGING AN AIRCRAFT AFLOAT BY BEARING PLATE

The bearing plate measures angle $BPL$ accurately. Then the sum of these angles (subtracting 360° from the sum if necessary) is the bearing of $L$ from the aircraft by compass; $324° + 70° = 394°$; $394° - 360° = 34°$. As the correct magnetic bearing is 30°, there is a deviation of $-4°$ on a compass course of 70°, or a magnetic course of 66°. Thus, the same result can be obtained from a bearing plate and steering compass as from a bearing compass.

It may happen that it is not convenient to take bearings in the manner outlined above. An alternative method is to mount a landing compass ashore on a site free from local magnetic fields and simultaneously to take bearings of the bearing compass or bearing plate in the aircraft from the landing compass and of the landing compass from the aircraft. It should be obvious from consideration of Figs. 93 and 94 that if $L$ be supposed to represent a landing compass, and the bearing of the aircraft was 210° from the landing compass, then by taking the reciprocal of 210° (i.e. 30°) as the correct magnetic bearing of $L$ from the aircraft the deviation can be obtained.

How in practice to swing an aircraft afloat can scarcely be usefully laid down, as so many various circumstances arise which may prohibit the adoption of any particular method. The vagaries of tide and wind, the number of the crew and amount of time available all require consideration. A few general remarks, however, may be made. If a motor-boat is available it will provide a convenient way of turning the aircraft round the buoy. In very favourable conditions, it may be possible to hold the aircraft steady on a particular course for a short time; when these

conditions obtain, the aircraft may be headed approximately on a cardinal or quadrantal point by reference to one of its own compasses. Usually, however, it will not be possible to hold the aircraft steady on any course for an appreciable time. It is then advisable to take a large number of bearings—say, one for every 12° or 15° of alteration of the aircraft's course. A curve should be plotted for the results obtained and a deviation card

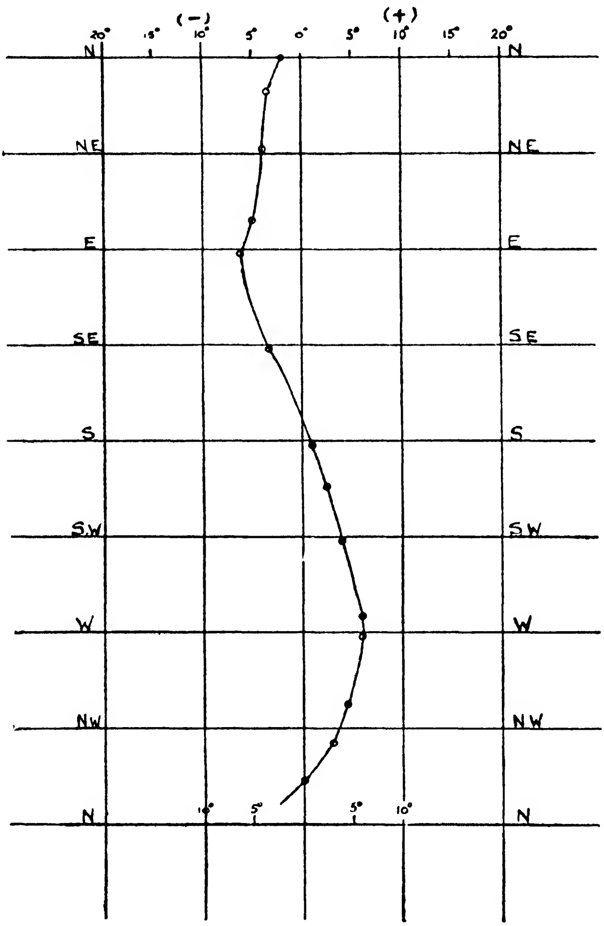



FIG. 95. CURVE OF COURSES

filled up from the curve. When it is necessary to take bearings, etc., as the aircraft is moving—even though the movement is slow—it is essential to good results that all observations be taken at the same time. Thus, suppose the bearing of a distant object be taken by bearing compass, one observer will be required to read the bearing and another the course from the bearing compass, while one observer is stationed at each of the other compasses in the aircraft. As the bearing is taken a pre-arranged signal should be given, all observations taken at once and immediately noted

down. If reciprocal bearings of a landing compass are being used, a clear code of signals between the shore and the aircraft must be devised.

The results of an actual swing of an aircraft afloat are now given in full. The aircraft was swung in a tidal river under adverse weather conditions by an experienced compass adjuster. Mist prevented observations of a distant object and no bearing compass was available. A prepared form was used as given in the following table.

| | (1) Course by Pilot's Compass | (2) Bearing by Bearing Plate | (3) Sum of Cols. (1) and (2) | (4) Landing Compass Reciprocal | (5) Deviation |
|---|---|---|---|---|---|
| (274) . | 268 | 48 | 316 | 322 | + 6 |
| (296) . | 291 | 26 | 317 | 322 | + 5 |
| (321) . | 318 | 2 | 320 | 323 | + 3 |
| (332) . | 332 | 354 | (686) 326 | 326 | 0 |
| (352) . | 355 | 336 | (691) 331 | 328 | − 3 |
| (16½) . | 20 | 308½ | 328½ | 325 | − 3½ |
| (44) . | 48 | 282 | 330 | 326 | − 4 |
| (78) . | 83 | 249 | 332 | 327 | − 5 |
| (94) . | 100 | 233 | 333 | 327 | − 6 |
| (136) . | 139 | 189 | 328 | 325 | − 3 |
| (181) . | 180 | 141 | 321 | 322 | + 1 |
| (207½) . | 205 | 113½ | 318½ | 321 | + 2½ |
| (229) . | 225 | 91 | 316 | 320 | + 4 |
| (264) . | 258 | 60 | 318 | 324 | + 6 |

The sum of Cols. (1) and (2) gives the equivalent to the bearing of the landing compass taken from the pilot's compass in the aircraft. Column (5) shows the deviation for the courses by compass in Col. (1). The magnetic courses corresponding to these compass courses were obtained; these are given in brackets on the left of the form. The curve shown in Fig. 95 was then plotted and the entry on the deviation card made as follows—

| For Magnetic Course | | Steer by Compass |
|---|---|---|
| N. | 0 | 2° |
| N.E. | 45 | 49° |
| E. | 90 | 96° |
| S.E. | 135 | 138° |
| S. | 180 | 179° |
| S.W. | 225 | 221° |
| W. | 270 | 264° |
| N.W. | 315 | 312° |

(Certain of the text and data appearing on pages 95–103 have been extracted from *A.P.* 1234, by kind permission of the Controller, H.M.S.O.)

CHAPTER VI

# GENERAL SERVICE ELECTRICAL INSTALLATION INCLUDING CONTINUITY AND INSULATION TESTS

## 26. THE GENERATOR

AIRCRAFT generators comprise various types of dynamic electric machines which, although of small output, are highly specialized in their characteristics and represent the latest development of light-weight design and manufacture. The generator is usually arranged for windmill (as here first considered) or sometimes for engine, drive (as secondly described).

### Air-driven Generator

A typical air-driven aircraft generator (bi-polar type) complete with cable plug (see Fig. 96) is here described. It is direct current shunt wound for an output of 500 watts at 12 to 14 volts D.C. when running at a speed of 4,500 r.p.m.

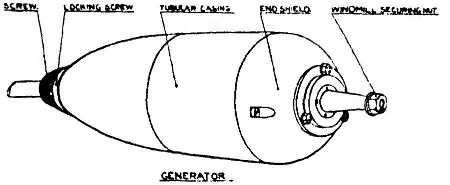



FIG. 96. GENERATOR

The body of the generator consists of an aluminium external tubular casing, with the field yoke fitted inside. The poles are formed integrally with the field yoke which is built up of laminated stampings. The field coils are laid round the pole pieces before the field is fitted into the external casing, the coil-overhang being taped up and varnished.

The aluminium end shield incorporates the front ball bearing which is designed to take the windmill thrust. The bearing is protected in front by a steel washer and an internal watertight gland, a second washer closing the bearing housing inside the end shield. Three screws are provided to bolt the two washers together and also secure the bearing to the end shield; the latter is fixed to the body of the generator by two bolts which pass through clearance holes in the field laminations and screw into the rear portion of the aluminium casing, the arrangement being such that the complete generator armature is withdrawn together with the front end shield. The forward end of the armature shaft is tapered to receive the windmill which is secured by a hexagon nut.

The armature core is built up of laminations and has twelve semi-closed slots in which the armature coils are laid, the slots being closed by fibre wedges which are driven in to secure the windings against centrifugal stresses. For the same reason, the end connectors and coil-overhangs are each bound with a layer of fine piano wire suitably insulated so as to prevent damage to the armature coil insulation.

The commutator is located at the rear end of the generator and has 36 segments. The rear portion of the generator, with spinning removed, is shown in Fig. 97.

The brush holders consist of two aluminium bridge pieces, which are secured to the bearing bracket by two bolts and are insulated from the brackets by flanged ebonite bushes through which the bolts are passed,

the flanged portions being on the brackets, while the nuts are insulated from the bridge pieces by mica washers. Two carbon brushes of rectangular cross section are mounted in each brush holder, the flexible leads being attached to the upper portion of each brush, which is copper-plated. Each brush is held in firm contact with the commutator by means of a pivoted arm, the extremity of which bears on the top of the brush, the bearing pressure being provided by small compression springs. The rear end of the generator is enclosed and protected by an aluminium spinning of streamline shape. The rear journal bearing is housed in the boss, which is formed between and cast integrally with two channel section arms forming an extension of the generator casing as shown in Fig. 96 above. A shoulder is formed at the rear end of the boss extension, the extremity being threaded to receive a locking screw. The end spinning fits over the threaded portion and is clamped between the shoulder on the boss and the locking screw. The connections to the generator are led in through a

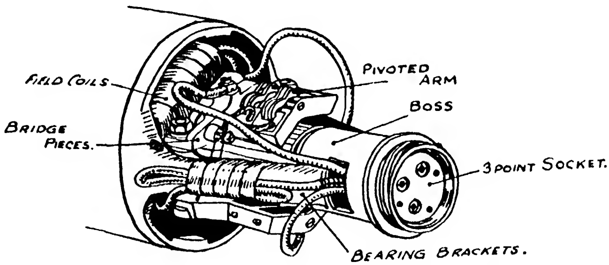



FIG. 97. GENERATOR WITH REAR SPINNING REMOVED

3-point plug and socket connection which is housed in the extreme aft portion of the generator.

The threaded portion of the boss is drilled and threaded internally, the 3-point socket being fitted and retained in the boss by a locking ring. The connections to the socket are soldered to tags brought through the back of the socket, connecting up being carried out before the socket is fitted; the 3-point plug is retained in position in the socket by a knurled screw which engages in the internally threaded portion of the boss.

The internal leads are brought out from the back of the socket through a rectangular aperture cut in the boss as shown. One lead is connected to each brush holder and the third permanently connected to the generator field. The leads are identified by coloured braiding, the colour for the lead to the positive brushes being yellow, the negative blue, and the field slate. The corresponding connections on the plug and socket are identified by sunken marks of yellow, blue, and slate.

The wiring diagram of the generator is shown in Fig. 98. The generator operates in conjunction with a voltage box. The external generator leads are connected to the yellow, blue, and slate terminals on the control box, a suitable resistance or field shunt being connected in parallel with the generator field as shown in diagram (Fig. 99).

When a 12-volt accumulator is charged from such a generator as here described, in conjunction with a voltage control box, the battery will be charged on the "constant voltage system," therefore the initial charging current when the battery is discharged may be three or four times the normal charging rate for the particular battery in use. This heavy current

only continues for a short time, however, and will not damage the accumulator. The charging current will fall steadily as the accumulator becomes charged, being practically zero when the fully charged state is reached.

Aircraft generators are designed with a minimum of copper and iron in order to reduce weight, and the temperature rise on continuous load of such machines is thereby much greater than in normal generator practice.

The reduction in weight output ratio is rendered possible by the extremely favourable conditions of cooling when the generator runs in the unobstructed slipstream of the aircraft's airscrew. If an aircraft generator is run on load on the ground for a lengthy period it will tend to overheat unless provision is made for cooling—the machine should therefore be run on the ground, with reduced load or cooled with a suitable air blast.

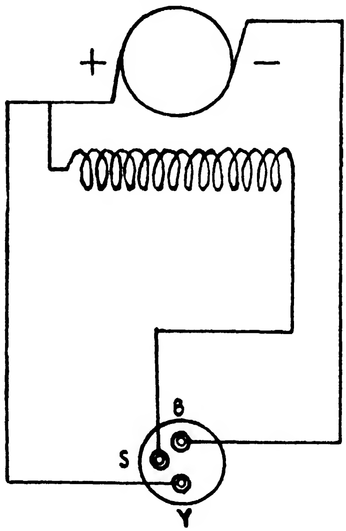



Fig. 98. Generator Wiring Diagram

Generators are manufactured to such specifications as will secure interchangeability of parts and give the required performance. In general, the generator is required to give a continuous output at full rating. In certain cases the generator is designed to take full advantage of the slipstream for cooling purposes, and the load run is then limited by the specification to half an hour. The normal fall of current due to temperature rise is compensated for by adjustment of the field regulator to maintain constant load. On conclusion of the load run the commutator is carefully examined. Any generator of which the commutator shows signs of pitting is rejected. Blackening of the commutator is slight and even all round the periphery; regularly spaced blackened segments alternating with bright segments are indicative of incorrect adjustment of the brushes or inherent bad commutation.

An overload 25 per cent in excess of the usual full load is customarily imposed.

The specification limits the speed at which the full output is obtained. "Inherent regulation" is usually expressed as a percentage of the rated load voltage and is obtained by observing the rise in voltage when the load changes from rated output (at rated voltage) to no load, at constant speed and without any external adjustment of the exciting circuit.

In the case of L.T. generators, as here described, all electrical parts must withstand the application of 220 volts A.C. between them and earth for a period of 1 min.

The test for insulation is made with a 500 volt megger immediately after the load run while the generator is hot; a lower value than 2 megohms is not accepted.

The limit for temperature rise above room temperatures is usually about 78° C. for low voltage generators. A telephone test for commutator ripple is made; such comparative tests often disclose defects such as incipient short circuits in the armature coils, defective soldering, etc.

Wherever possible a check test is made with the generator operating with its associated equipment (e.g. voltage control box, etc.).

The faults most frequently met with in generators, and the methods of testing and correcting, are—

Incorrect marking of the output plugs or socket, leading to cross connections when coupled to an external circuit: A test is made with the generator coupled to its load by means of the actual plugs provided.

Poor commutation leading to failure to excite, or, sparking under load. The commutator must be dead true both before and after test, the mica undercut (if so applicable), the brushes correctly bedded and free in their holders, and the whole armature perfectly balanced both statically and dynamically. It must be seen that the proper grade of brush is fitted and that the brush gear is in correct angular position and is truly rigid.

The driving end of the armature shaft is generally turned to a standard taper or otherwise adapted to carry a standard windmill, all mechanical dimensions at this point being carefully checked to ensure interchangeability.

Defective ball bearings: it sometimes happens that the race or its housing is of incorrect dimension and gives rise to unusual vibration and noise at full speed running.

End play is also checked and the radial tightness of the bearing proper should be such that there is no appreciable shake at working temperature conditions.

Armature whip is sometimes met with and is revealed by the armature rubbing against the pole pieces. This rubbing is often very difficult to detect, as it may only develop under full load and causes little more trouble than an increased rise of temperature. Whip is generally caused by a sprung shaft or by an armature imperfectly balanced statically or dynamically; these points must therefore be carefully watched.

Locking screws are a frequent source of trouble. As a dynamo is subjected to intense vibration from various sources it is important that all screws be adequately locked, and attention to this detail is imperative. The method of locking is not so important as the manner in which it has been done.

Loose field stampings occasionally give rise to serious trouble. The method of securing the stampings in position and preventing their rotation must be investigated, and the rigidity of the stampings tested.

Slack internal connecting leads are examined; if these are not securely anchored they sometimes come adrift and foul the revolving parts.

Metal dust in the bearing housings or in the armature tunnel. The stray magnetic field iron filings, etc., tend to resist ordinary methods of removal, and special precautions must be taken to see that the whole machine is free from metal dust and filings.

Armature bearings and wedges must be permanently secure. Shrinkable material which might cause ultimate failure must not be used in such positions.

The following procedure must be adopted before a generator is accepted—

See that the commutator is clean and free from any traces of grease or paint.

That the brush gear is free from carbon and copper dust.

Rotate the armature slowly by hand to confirm that no binding has developed during the cooling down after the load run.

Examine all end inspection covers for fit and weather proofing properties. (Where spares are stored in a box on the generator they are individually

packed in such a manner that they cannot be damaged by rubbing against one another.)

See that the shaft and other bright steel parts are treated for rust prevention by the application of vaseline, grease, or other suitable means.

Check the marking on the label: type identification, serial number, maker's name, year of manufacture, speed in revolutions per minute, output in volts and amps.

Aircraft generators are controlled automatically to give constant voltage irrespective of the load and speed (within certain limits); the average speed is generally about 5,500 r.p.m., but generators operate between approximately 4,000 r.p.m. and 7,500 r.p.m. Generators are, as already mentioned, usually driven by means of windmills coupled to the front end of the generator. The windmill should be properly mounted with its boss on the shaft and locked in position; it should be regarded as a small airscrew (see "Airscrews").

The generator should be mounted on a proper base or in a suitable cradle on the aircraft. It should be away from vapour and flame emitted by the engine, should be kept free of petrol, oil, water, or spray, and clear of anything by which it could be fouled or damaged. It should be kept clean.

The generator is mounted with its axis of rotation parallel to the horizontal datum line of the aircraft and in the unobstructed airscrew slipstream in such a manner that its whole body is exposed to the air flow. The close proximity of struts or other parts of the aircraft structure either forward of or abaft of the windmill must be avoided, as such obstructions may so distort the air flow past the generator that its performance is seriously impaired.

Connections to the generator are, as already mentioned, by means of a plug and socket fitting, the socket being permanently fixed to the generator with internal connections complete. This enables the generator to be quickly removed when not required.

The generator should be so mounted that the supply cables may be readily connected and disconnected; enough clearance must be allowed to permit the easy removal of the end fairing for the examination of the commutator and brush gear without disturbing the main body of the generator.

The generator cradle should be fitted so that the strap may easily be detached when it is required to remove the generator from the aircraft.

In order to avoid compass deviation due to the generator, the generator should be mounted as far as possible from the compass. In aircraft of metal construction the generator mounting, which should itself be of non-magnetic material, should be kept well away from any member of the aircraft which passes near the compass.

Air-driven generators can usually be run up to speed on the aircraft for testing purposes (though not usually to full load) by running the engine on the ground. A satisfactory voltage regulator test, as later described, will also show that the generator is in running order. If a doubt exists as regards its ability to give full output, arrangements should be made for a test by a portable engine with a flexible drive, or the apparatus should be removed for bench test. The following matters should receive attention from time to time—

The bearings should be free. These are usually packed with grease and need no oil.

Commutators should be kept clean and, when necessary, polished with fine grade glass paper.

The grooves between the commutator segments should be free from copper dust and dirt. A fine pointed scraper may be used to clean out the grooves.

Brushes should bed evenly on the commutator and work freely in their holes, the spring transmitting an even pressure of the brush on the commutator.

The bolts securing the brush carrier to the frame should be tight.

## Field Shunt

A suitable resistance connected in parallel with the field windings of such a generator as has been described improves the performance of both generator and the control box by—

(*a*) Reducing sparking at the control box.

(*b*) Improving commutation.

(*c*) Increasing generator output.

The shunt consists of a resistance unit totally enclosed in a sheet metal case. The resistance element consists of a flat mica former, wound with 33 S.W.G. bare Eureka wire to a total resistance of 25 ohms. The ends of the resistance wire are brought out to terminal tags on to which are soldered two 8-in. leads of uniflex 4 cable. The terminal tags are riveted in position on the mica former.

The former is mounted between sheets of micanite suitably grooved to accommodate the flexible leads and terminal tags, the grooves being filled with shellac during assembly.

The aluminium case is made in two portions, the front being bent or folded round to enclose the resistance element and the back cover; the whole is then riveted together by means of four brass eyelets, which also form holes for four fixing screws. Washers are riveted in position under the eyelets on the back of the unit to ensure that the shunt stands clear of its mounting when screwed in position. Free circulation of air round the unit is thus permitted.

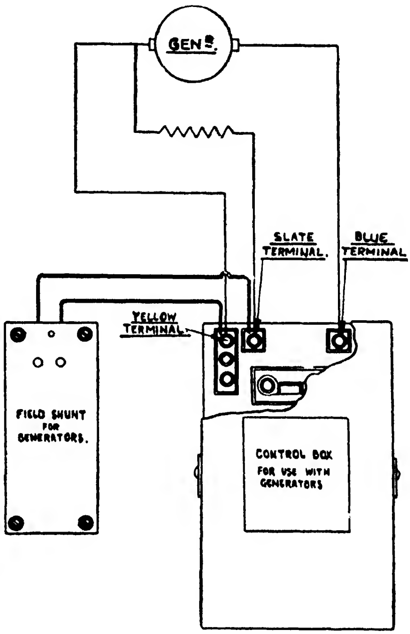



FIG. 99. GENERATOR, VOLTAGE CONTROL BOX AND FIELD SHUNT; METHOD OF CONNECTION

The shunt should be mounted as close to the control box as possible, and in a vertical position, to permit free circulation of air round the shunt. The flexible leads should be connected to the yellow and slate-coloured terminals of the voltage control box, thus putting the resistance in parallel with the generator field as shown in Fig. 99.

When installing the shunt care should be taken to cleat the leads securely and as close to the shunt as possible.

## Voltage Control Box

(For control of the air-driven generator described.)

The generator, as already stated, is controlled by means of a voltage

control box. This system of control maintains the voltage at a constant figure. It is used in conjunction with all shunt-wound generators which are not self-regulating. (The apparatus may vary, for example, a late type (vibrating reed type) of control box also incorporates within itself a generator field shunt, instead of this item being separately installed, as is the case in connection with the box here dealt with.)

The apparatus, the arrangement of which is shown in Fig. 99, incorporates a cut-out which automatically disconnects the battery from the charging circuit if the battery begins to charge back into the generator. From Fig. 100 it will be seen that a solenoid coil $L_1$ is connected across the generator armature terminals. In series with this winding is connected a fixed ballast resistance $R_2$. As soon as the generator terminal voltage rises beyond a predetermined value the solenoid operates and breaks the contacts $S_1$ by the attraction of the armature $A_1$. This armature is connected to the lower right-hand terminal via the iron core of the solenoid; this connection is therefore shown by a dotted line in the diagram. The breaking of the contacts $S_1$ connects the regulating resistance $R_1$ and the "bucking" winding $L_2$ in series between the generator field terminal and the negative armature terminal. This weakens the generator field, and the terminal voltage immediately falls. As soon as the voltage falls below normal, the armature $A_1$ is pulled away from the solenoid by a control spring. The resistance $R_1$ and the bucking winding $L_2$ are then cut out from the circuit.

The battery cut-out consists of a solenoid coil $L_4$, which is connected between the positive battery connection and the positive generator connection. When the generator is supplying current the coil $L_1$ energizes the iron core of the main solenoid, and the armature $A_2$ is thereby magnetized to a definite polarity and attracts the main solenoid, thus closing the bridge contacts $S_2$.

The current through the solenoid coil $L_4$ flows in such a direction as to assist the action of the main solenoid by attracting the armature $A_2$ about its pivot. It should be noted that the battery is connected across the terminals $B_1$, and $B_2$ as shown. When the battery commences to discharge into the generator the current through $L_4$ is reversed and the solenoid acts in opposition to the main solenoid. The contacts $S_2$ now break and the generator armature circuit is disconnected from the control box.

The component parts are mounted on a hollow rectangular aluminium base, which is closed by an aluminium back plate lined with mica to eliminate fire risk. The front aluminium cover is held in position by two brass catches. Inside the cover is a diagram of connections, together with instructions for adjustment.

The instrument should preferably be mounted in a protected position, in order to secure maximum cooling effect, and in such a way that adjusting screws can be readily manipulated (this remark also applies to any separate battery cut-out which may be in any special installation). When handling the control box with the cover removed, care should be taken not to bend or damage any of the springs or moving parts, and to prevent any foreign matter, especially metal such as wood screws, from becoming lodged in the apparatus during installation.

The instrument is supplied by the makers correctly adjusted and ready for use, and except when necessitated by imperfect operation the various adjustments should not be interfered with. (The voltage setting should not be changed provided the voltage is between 13·5 and 15. Under these conditions with a 12-volt 25 amp.-hour accumulator in good condition, all navigation lights can be kept on continuously during all night services.)

The cover should always be kept on to protect the instrument from accidental damage.

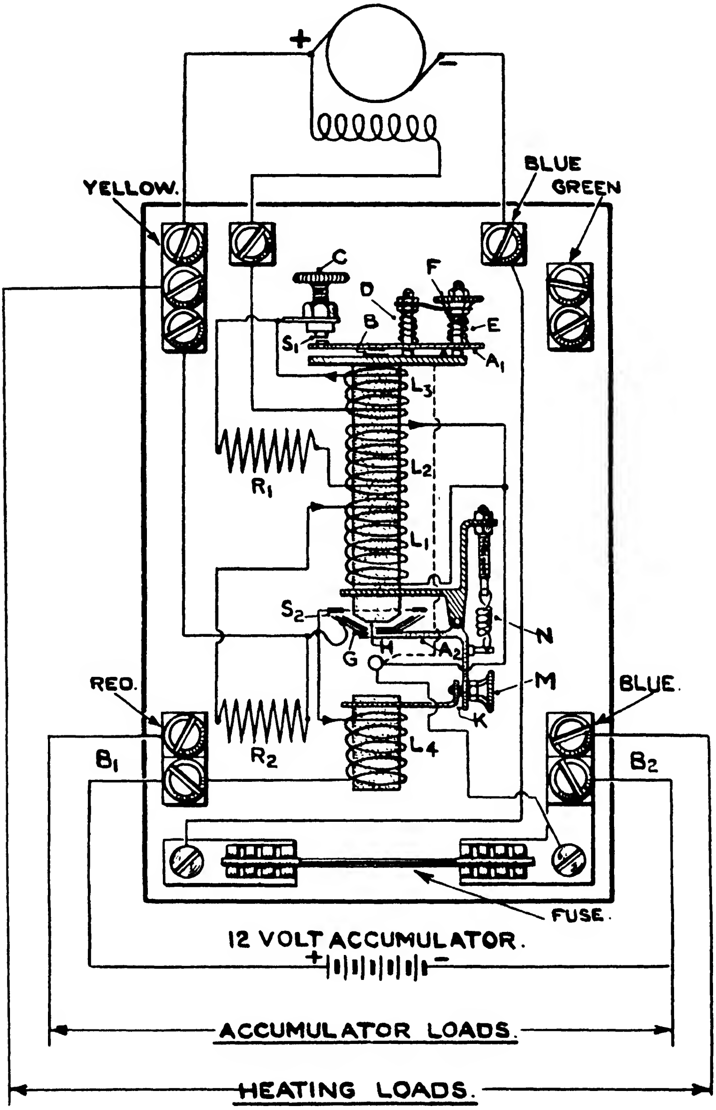



FIG. 100. VOLTAGE CONTROL BOX—DIAGRAM OF CONNECTIONS

The regulator is set to give 13·5 volts when cold; during flight this may rise to 15 volts, owing to temperature effects, but the average value should be about 14 volts.

The battery cut-out is set to close at about 12·5 volts and cuts out with a discharge current of about 4 amps. The magnetic circuit of the battery cut-out is arranged to react on the main solenoid circuit in such a manner that a charging current into the battery has the effect of slightly reducing the generator voltage, the reduction in voltage being dependent on the charging current. The voltage change is, however, small, being about ·5 volts, with a charging current of 15 amp.

The foregoing effect is an advantage because it tends to limit excessive charging current into the battery, which is almost discharged. As the battery voltage rises the charging current is reduced, and the generator voltage rises accordingly until the battery is fully charged and is floating with full voltage from the generator.

The vibrating contacts of the regulator should be clean and the carrying arm free in its bearings.

The brush blades of the cut-out should be clean and making good contact when the cut-out is in charging position.

Tests are made with a portable voltage tester. This instrument contains a voltmeter with flexible leads and plugs for connecting it to the regulator; the instrument, which incorporates a telephone jack, provides a simple means for testing whether the controller is maintaining the correct generator voltage, and the telephones give an aural indication that the regulator is in operation. Instructions for use of the testing instrument are to be found inside the cover.

With full load on the generator some sparking will be observed at the regulator contacts. This is quite normal and has no adverse effect.

If any voltage adjustment is required during flight, the tension of the front control spring on the upper armature should be adjusted by the milled screw *F*. No other adjustment should be attempted when in the air; other adjustments should be made during overhaul on the ground.

At the end of every 100 flying hours the control box should be carefully overhauled. The regulator and battery cut-out contacts should be carefully cleaned and readjusted, the method being as follows—

(*a*) Disconnect the battery leads.

(*b*) Remove the armature $A_1$ and the screw *C*.

(*c*) Clean and burnish the contacts $S_1$ and replace armature and set screw. See that the contact faces are parallel after cleaning.

(*d*) Set the air gap *B*, the armature and solenoid core to the thickness of a ·015 in. feeler by the adjusting screw *C* and tighten up the lock nut. When setting the air gaps see that the contacts are closed and the armature properly seated on the fulcrum.

(*e*) Tighten up the tension spring by giving two complete turns of the securing nut and tightening up the lock nut.

(*f*) With the generator running at 4,000–5,000 r.p.m. and the voltmeter connected across the yellow and blue terminals, set the voltage to 13.5 by adjusting the tension of the spring *E* by means of the screw *F*, and after adjustment secure with the lock nut.

To adjust the battery cut-out—

(*a*) Disconnect from the accumulator and remove the armature $A_2$.

(*b*) Clean and burnish the contacts $S_2$ and replace the armature.

(*c*) Adjust the bridge contacts *G* to obtain even contact; when contact is just made the air gaps should be the thickness of a ·015 in. feeler.

(*d*) Set the stop screw *M* to give maximum opening of the air gap *H* to thickness of feeler.

(*e*) With the generator running, adjust the tension of the spring *N* until the contacts close at approximately 12·5 volts.

(*f*) Connect the accumulator and finally adjust the spring *N* until the contacts open with a battery discharge current of 4–5 amp.

After adjustments tighten up all lock nuts.

*Note.* On some control boxes a single pole fuse is placed in common negative main circuit; in others there is no fuse, all fusing being done externally.

## Engine-driven Generator

The generator here described is the alternative of the air-driven type and has an output of 500 watts at 14 volts at about 5,000 r.p.m. at normal cruising engine speed. It is directly driven from the engine and in connection with the accumulator is self-regulating.

A suitable accumulator cut-out and a manually operated position switch, together with a resistance enables the charging current to be

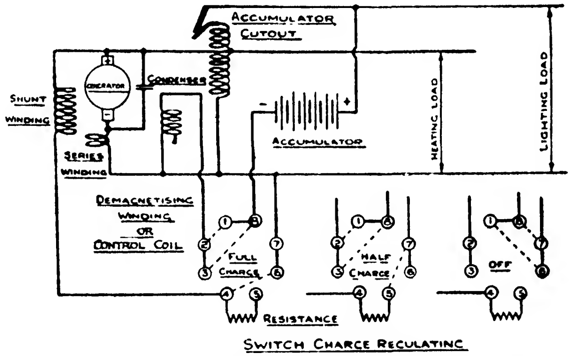



FIG. 101. ENGINE-DRIVEN GENERATOR—DIAGRAM OF CONNECTIONS

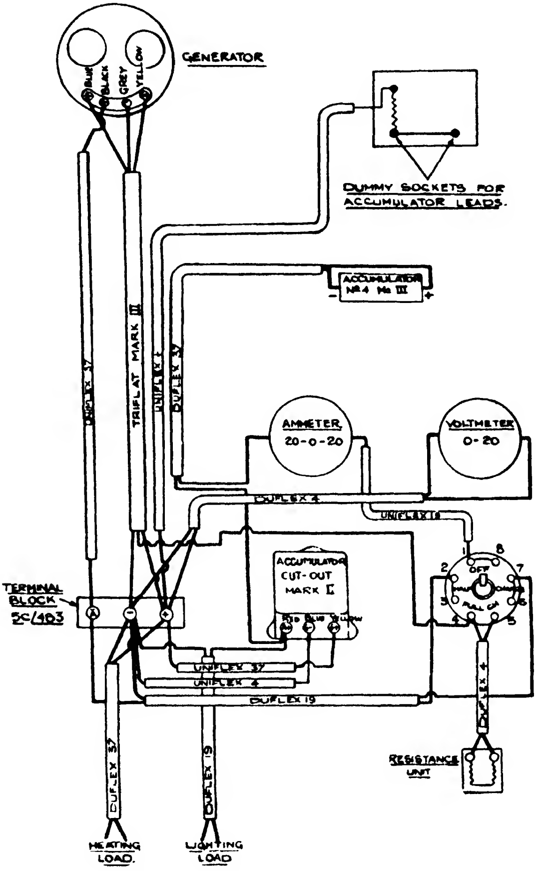
reduced when the accumulator becomes fully charged, or the generator to be switched off completely.

The control of the generator is effected by special field windings in connection with the accumulator. The shunt-field winding is connected across the lines, and the armature current is passed through a series winding to give load compensation as in an ordinary compound wound generator. The control winding is of low resistance and wound in the reverse direction, and carries the accumulator current only.

When the system is in operation the voltage of the generator rises until the cut-out contacts close and charging current flows to the accumulator. This charging current, flowing through the control winding, exerts a demagnetizing force on the field system and prevents any further material rise of voltage. Thus, as the speed of the generator increases the charging current automatically rises just sufficiently to give the necessary reduction in field strength and maintain the line voltage approximately equal to that of the accumulator. As all external load currents are supplied directly from the generator, and do not pass through the control winding, the charging current and voltage control are independent of the load conditions. When the generator falls below the minimum speed at which it can supply the load connected, the cut-out contacts open and lighting loads are maintained from the accumulator through the control winding, which is of low resistance.

The line voltage under normal conditions is always slightly in excess

of the accumulator voltage and as the latter rises as the accumulator approaches the fully charged state, a switch is provided to reduce the charging rate, thereby restoring normal voltage and avoiding excessive overcharging. The switch has three positions: "off," "half charge," and




WIRING DIAGRAM.

ENGINE DRIVEN SELF-REGULATING 500 WATT.

GENERATOR

FIG. 102. ENGINE-DRIVEN GENERATOR—WIRING DIAGRAM

"full charge." The effect of moving the switch to the "half-charge" position is to insert the resistance unit into the shunt-field circuit of the generator. When the switch is in the "off" position, the accumulator is connected directly to the lighting mains, and the generator shunt and control field circuits are broken, thus preventing excitation of the generator.

Dummy accumulator sockets are wired to the system in such a way

as to prevent excitation of the generator if the aircraft is flown without an accumulator. This is effected by connecting the negative accumulator lead to the generator positive lead, thereby converting the generator control winding into a powerful shunt winding of demagnetizing polarity when the control switch is in the charge positions. Connection to the positive accumulator lead is immaterial, but the dummy terminals are connected together so that in stowing the leads polarity need not be observed.

A small resistance (about 1 ohm) is incorporated in the dummy terminal block. The object of this is to limit the short-circuit current which would flow in this circuit due to the residual generator voltage where the control switch is in the "off" position.

With the control switch in the "off" position the generator is out of action, and the lighting loads and essential services are supplied from the accumulator. At the beginning of a flight, the switch should be placed in the "full charge" position, when the generator will supply all loads connected and in addition charge the accumulator at about 3 amps.

After a time, depending upon the initial state of the accumulator, the fully charged state will be approached. This will be shown on the voltmeter by a rise in voltage which, if allowed to continue, may possibly reach 17 volts. The switch should be moved to the "half-charge" position when the voltage exceeds 14½ volts. This reduces the voltage to about 14 volts and the charging rate to a small value (0 to 1 amp.). Where a fully charged accumulator is placed in the aircraft this effect will usually occur in the first few minutes. Throughout the remainder of the flight no further attention should be necessary.

It is imperative that the engine should not be run unless the accumulator leads are properly connected to an accumulator or stowed in the dummy sockets provided. A faulty connection in this circuit will lead to excessive voltage and damage to the generator and any services connected if the control switch is inadvertently placed in the "charge" position.

## 27. ACCUMULATORS

### Lead-acid Accumulators

(No account is here taken of ordinary bench recharging, as it is considered beyond the normal function of the ground engineer. Charging from the generator has already been dealt with.)

Accumulator cells (see Fig. 103) usually consist of several positive and negative plates (generally made of lead and paste filled), arranged alternately throughout the cell.

Each positive plate has a negative plate on each side of it. The plates are prevented from touching by separators, usually celluloid, ebonite, or wood partitions arranged so as to permit free circulation of the electrolyte between the plates. If this is impeded by any means, the electrolyte will not be of uniform density throughout the cell, which will result in buckling of the plates and the shedding of active material.

The separators always have vertical grooves further to allow of the equalization of the electrolyte density. A certain amount of space is left between the bottom of the plates and the separators to allow any active material which may be shed in the form of sediment to fall to the bottom of the container clear of the plates, which it would otherwise short circuit. The electrolyte in all ordinary cells consists of sulphuric acid of a specific gravity of 1·84 diluted with distilled water to a specific gravity of 1·27. The specific gravity of the electrolyte may be tested by a hydrometer, several special kinds of which are obtainable for this purpose.

For aircraft purposes the weight and size of accumulators are kept at a minimum with some sacrifice in life.

The normal useful life of such accumulators in temperate climates may be reckoned as about 70 complete cycles of charge and discharge at the 10-hour rate, or 700 working hours at 10 hours a day. If the working hours are 5 per day then the useful life would be approximately 2,000 hours; it may be thus said that the useful life may be taken as from three to five months.

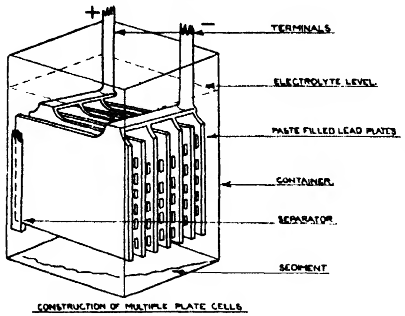



FIG. 103. ACCUMULATOR—CONSTRUCTION OF MULTIPLE PLATE CELLS

Under tropical conditions the life may be very considerably shortened, even to one or two months.

By useful life is meant the number of cycles of charge and discharge which reduces the original cell capacity to 40 per cent. In tropical climates frequent inspection is necessary and evaporation of the electrolyte, if rapid, should be compensated for by "topping up" daily with distilled water.

The voltage of an accumulator in a fully charged condition is practically a fixed quantity. On open circuit the potential difference between the positive and negative plates is usually about 2·2 volts. The terminal voltage falls as the cell discharges, the rate at which the voltage falls being dependent on the rate of discharge. In Fig. 104 a curve is given showing the fall of the voltage on discharge at the 10-hour rate.

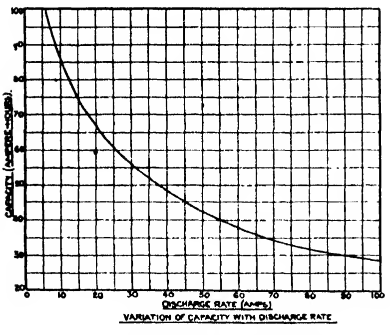



FIG. 104. VARIATION OF CAPACITY WITH DISCHARGE RATE

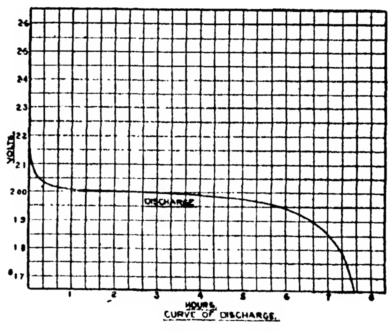



FIG. 105. CURVE OF DISCHARGE

The capacity of an accumulator is its output expressed in ampere-hours. The capacity thus represents the product of the current (in amperes) and the time (hours) for which that current can be taken from the cell when fully charged until the terminal voltage falls to 1·8 on load. The normal rated capacity of a cell is usually based on the 10-hour rate of discharge, i.e. the current which will discharge the cell to 1·8 volts in 10 hours; when this discharge rate is exceeded the capacity is reduced. It should be realized that a 40-amp.-hour accumulator will not give 20 amp. for 2 hours

nor 10 amp. for 4 hours; it is rated to give 4 amp. for 10 hours, and if the discharge current exceeds 4 amp., the ampere-hour capacity will be reduced. For example, in Fig. 105 if a 2-volt 90 amp. accumulator is considered—

| | | | | |
|---|---|---|---|---|
| At the 10 hour | rate | its capacity is | 90 | amp.-hours |
| ,, 5 hour | ,, | ,, | 75 | ,, |
| ,, 1 hour | ,, | ,, | 45 | ,, |

This means that the accumulator will give 9 amp. for 10 hours, 15 amp. for 5 hours, or 45 amp. for 1 hour. In each instance the current rating of the accumulator for the period specified is that which would bring the terminal voltage of the cell down to 1·8 on closed circuit starting from the fully charged condition. The capacity of any cell is not, therefore, a constant quantity, but depends on the amount of active material in the plates.

## Faults

The following faults may be attributed to improper treatment of free acid accumulators—

Sulphation, hydration, buckling of plates, disintegration of plates, internal short circuit, damaged containers.

*Sulphation* is the most common fault, generally caused by neglect by (*a*) discharging below 1·8 volts per cell, (*b*) allowing to stand partly or wholly discharged, (*c*) continuous undercharging, (*d*) using too strong an electrolyte.

The treatment for sulphation consists of (1) emptying and washing out with weak electrolyte; (2) refilling with weak electrolyte (specific gravity about 1·15); (3) sending for charge at one-quarter the normal rate with instructions to allow to gas steadily, thereby dislodging insoluble sulphate which falls as sediment. (It may be necessary to continue this charge for 100 or more hours.) (4) emptying out, washing out sediment with weak electrolyte and filling up with normal fresh electrolyte; (5) charging the cell at the normal charging rate for a short period.

Should the above treatment not be successful in removing the insoluble sulphate, the cell may be carefully dismantled and the plates taken out, scrubbed, and scraped carefully to remove hard sulphate. Great care is essential in order not to disturb the paste or active material of the plates in any way. Re-assemble the cell and place on slow charge until restored to normal condition. However careful the treatment, it should be noted, of course, that the life and capacity of the cell will have been impaired by sulphation.

*Hydration* is caused by allowing water to remain in contact with the active material of the plates for a long time. New accumulators should not be rinsed out with distilled water before the first charge. Hydration interferes with the chemical changes which take place during charge and discharge and impairs capacity. Treatment consists of prolonged charging on the lines of (3).

*Buckling of Plates* is generally due to excessive rates of charge and discharge causing uneven chemical action in the active material of the plates, which are thereby buckled by the stress. To remedy, the plates should be taken out and pressed gently between pieces of board, due care being given to the brittleness of the plates and the likelihood of loosening active material and causing shedding.

*Disintegration of Plates* may be caused by general neglect, prolonged overcharging and continuous charging at current strengths much less

than those indicated on the label; the result is peroxidation. There is no remedy. The consequent sediment should be removed to prevent it short-circuiting the plates, the cell being carefully shaken and emptied, filled with fresh electrolyte and sent for charge at one-half the normal rate.

*Internal Short Circuits* will be indicated to the persons responsible for charging. They may be caused by neglect or by lead "growths" (which will expand when warm) due possibly to prolonged undercharging below the normal rate. The plates should be taken out and cleaned of any excrescences.

*Damaged Containers* may result from stopped-up vent holes. When sending for charging, those responsible should be informed of any sealed vents. Celluloid cased accumulators should be kept out of the discolouring and strength reducing heat of the sun. High temperature from any source may cause discoloration and warping and cracking of containers, sulphation, hydration and buckling of plates, inability to hold charge, and expansion of positive plates during charge to such an extent as will result in entire failure.

## Inspection

Terminals should be tight and a light coat of vaseline should be applied to prevent detrimental effects due to acid. Vent plugs should be tight. The electrolyte should be kept to the proper level in accordance with instructions or level-mark. Cables to the accumulator must be correctly attached as regards polarity—red cable to positive and blue to negative. The cable terminals should be fitted in a dummy plug when not in use. Accumulators should not be left in an uncharged or partially charged condition, as either will lead to sulphation. When not required for use they should be given a freshening charge at least once a month.

## Test

The condition of an accumulator can be ascertained by a discharge test at the 10-hour rate (discharging at a current equal to one-tenth the nominal capacity) and the voltage recorded against time. A fully charged accumulator will give about 2·1 volts at the start of this test and not less than 1·8 volts per cell after 10 hours. If the voltage falls to 1·8 in less than 6 hours it will indicate that the accumulator is not in a very serviceable condition. Accumulators must be wholly of the non-flame or non-flame-top type, and preferably non-spillable (in acrobatic aircraft they are compulsorily so). They must be kept as far as possible from fuel tanks and engine.

The accumulator should always be protected from the weather, housed clear of all the usual places of passenger occupation and of all hand and walk ways, etc., but of course should be easily accessible at all times for inspection, test of electrolyte, voltage, etc., recharging and general maintenance. Care should be taken that it is securely fastened and locked in place, taking into account vibration. All live parts of the accumulator must be enclosed or protected. The box or compartment into which the accumulator goes must be adequately vented, must insulate the accumulator's celluloid sides (if applicable) from the air, and it must be entirely leak-proof. Spilled acid is highly destructive to most materials; it may find its way to a stressed member of the aircraft and by its rapid attack cause structural failure. Any signs, therefore, of free acid must be at once investigated.

**Alkaline Accumulators**

The nickel-iron accumulator is now very often used in place of the lead-acid type and owing to its long life and durability is especially suited for use in aircraft where the working conditions are extremely vigorous.

The positive and negative terminal places are perforated nickel-plated steel containers which are filled with the active material. The plates are welded or bolted together for similar polarities and separated by strips of hard rubber. Each cell container is a thin welded nickel-plated steel box entirely closed except for a special non-spillable gas release-valve which effectively prevents spilling of the electrolyte while allowing the gases generated during charging to escape. An important characteristic of this cell is that it may be charged or discharged at a very high rate and left in a discharged condition without injuring it in any way.

*Accumulators* must be capable of supplying navigation lamps, identification and landing lights, etc., and all services where continuity and existence of current is essential for at least 30 min. after the generator has stopped.

## 28. LOW TENSION INSULATED CABLES

There are many different classes, all L.T., of cables used in the electrical general service equipment of aircraft. Each class has a different number of cores from that of any other class. The cores consist of stranded tinned copper insulated by pure vulcanized rubber sheaths and wrapped in coloured cotton. In some cases the rubber sheathing itself is coloured. The number of cores comprising the cable of each class is indicated by the prefix of the class name (see Fig. 106).

Thus the class of cable containing a single core has a prefix "uni" that containing two cores "du," that containing three cores "tri," and so on. In nearly every class there are four types of cable; each type differs from the others in its class by the nature of the sheath in which the cores are enclosed. The nature of the covering sheath is indicated by the suffix of the class name; thus: the suffix "flex" (flexible cables for general use in protected positions) indicates that the core or cores are covered by a sheath of braided cotton; the suffix "proof" (waterproof cables) indicates that the cores are covered with a braided waterproof material; the suffix "sheath" indicates that the cores are enclosed by a tough rubber sheath for use in unprotected positions where they are liable to be rubbed against or otherwise roughly treated. The numeral following the name of the cable denotes the permissible current carrying capacity of that particular cable. Thus "uniflex 4" will carry 4 amp. "duflex 19" will carry 19 amp., and so on.

At standard current rating and for small cables up to and including 19 amp., all the sizes allow a drop of ·1 volt per yard run, 37 amp. cables allow a drop of ·1 volt per yard and a half run, 64 amp. cables allow a drop of ·1 volt per two and a half yards run. In the fifty power cables carrying 175 amp. the voltage drop is ·1 volt per yard run.

The fourth type of cable is of the sheath type closely braided with metal wire and is for use in aircraft in which directional wireless is installed.

In addition to these cables is a cable known as "Tripod" which is similar to "tri-sheath," except that it has cores of different colours. Tripod is a metal wire braided cable.

Special cables, "Triflat," are used for connecting up generators. The cables consist of three insulated cores contained in a shallow sheath of tough rubber. Triflat is also supplied braided with metal wire.

The cable known as fifty power is for connecting up electric starter motors. The core is a large diameter-stranded cable insulated by pure

vulcanized cambric tape and by one plain and two oil-resisting layers of varnished cambric tape. It is closely braided with paint impregnated cotton.

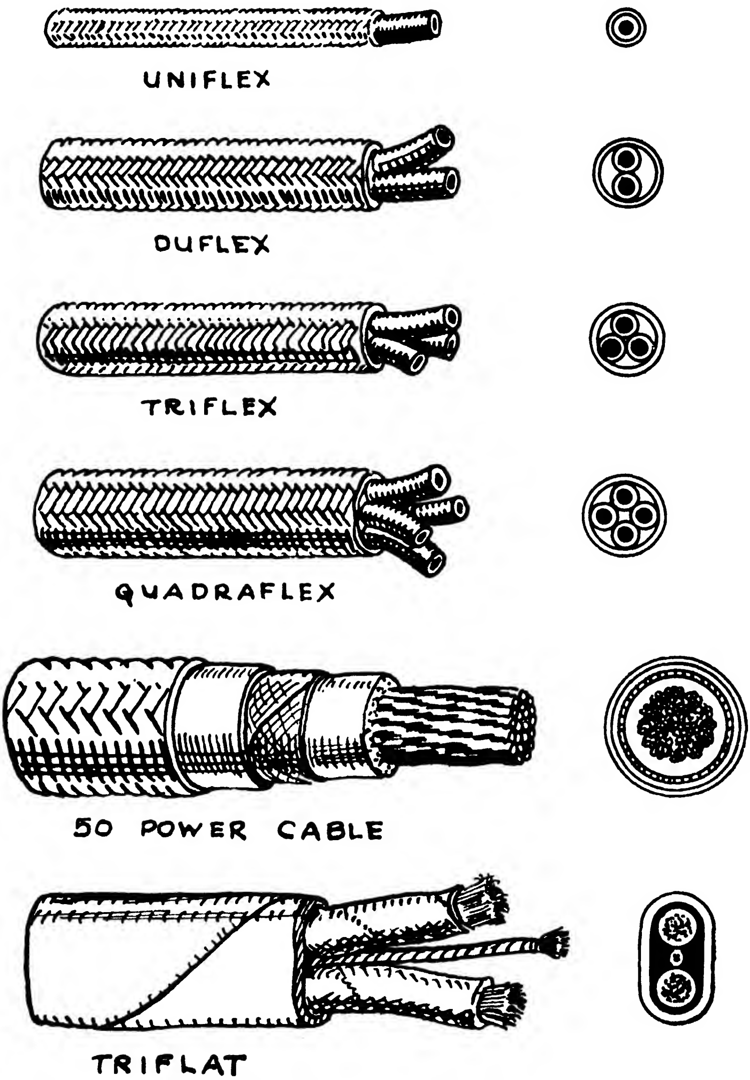



FIG. 106. TYPES OF CABLE

For instrument lighting a cable known as "instruflex" is used. This consists of two plain stranded copper cores insulated and wrapped respectively with red and black cotton. The cores are not enclosed in a sheath but are twisted together.

Below is given a list of stranded low tension cables—

| *Type* | *Number.* |
|---|---|
| Uniflex | 4, 7, 19, 37, 64. |
| Uniproof | 4, 7, 19, 37, 64. |
| Unisheath | 4, 7, 19, 37, 64. |
| Unisheath braided | 4, 7, 19, 37, 64. |
| Duflex | 4, 7, 19, 37, 64. |
| Duproof | 4, 7, 19, 37, 64. |
| Dusheath | 4, 7, 19, 37, 64. |
| Dusheath braided | 4, 7, 19, 37, 64. |
| Triflex | 4, 7, 19. |
| Triproof | 4, 7, 19. |
| Trisheath | 4, 7, 19. |
| Trisheath braided | 4, 7, 19. |
| Tripod | |
| Tripod braided | |
| Triflat | |
| Triflat braided | |
| Quadraflex | 4, 7, 19. |
| Quadraproof | 4, 7, 19. |
| Quadrasheath | 4, 7, 19. |
| Quadrasheath braided | 4, 7, 19 |
| Twensevenflex | 2. |
| Fifty power | |
| Instruflex | |
| Quintoflex | 4, 7. |
| Quintoproof | 4, 7. |
| Quintosheath | 4, 7. |
| Quintosheath braided | 4, 7. |
| Sextoflex | 4. |
| Septoflex | 4. |
| Nonoflex | 4. |

Where screened metal-braided cables are required in an exposed position, and where there is a danger of damage or corrosion to the braid, the following are used—

| | |
|---|---|
| Dumet | 4 T.R.S. |
| Tumet | 4 T.R.S. |
| Quadramet | 4 T.R.S. |
| Quintomet | 4 T.R.S. |

The letters T.R.S. indicate a tough rubber sheathing over all.

Lately, cellulose varnished cables have come into use; these follow upon the lines of the above, being named unicel, ducel, tricel, and numbered 4, 7, 19, etc., as the case may be.

It should be borne in mind that all cables here dealt with are designed with special regard to lightness in weight and they are not suitable for hauling through small holes or other confined spaces. Every precaution should be taken that they are not subjected to undue stress.

Electrical systems which the cables are called upon to serve may be grouped under these headings: ignition, wireless, intercommunication, and general.

For the purpose of recognition the cables serving the various systems have coloured coverings or are coloured distinctly during their installation and are secured by appropriately coloured cleats. The colour scheme is as follows—

| | |
|---|---|
| Ignition | blue |
| Wireless | red |
| Intercommunication | green |
| General | yellow |

The colours are also borne by the ends and the respective cleats and elsewhere to allow the run of the cable to be traced. Where cleats are inadmissible the cables are painted with bands of their distinguishing colours.

The cores of the various types of cable are wrapped in coloured cotton lapping as already mentioned. The colouring denotes the polarity or function of the core.

The general colour scheme is as follows. Single colours are used as far as possible, and extensions of these colours are employed for multiple cables. Those in most common use are—

Single core, natural colour.
Two cores, red and blue.
Three cores, red, blue, and green.
Four cores, red, blue, green, and yellow.

The key colours for main circuits are—

| | |
|---|---|
| Red . . . | accumulator positive circuits. |
| Blue . . . | negative, all circuits. |
| Green . . . | neutral. |
| Yellow . . . | generator positive circuits. |
| White . . . | used as special cases demand. |
| Grey . . . | generator field conductor in triflat cables. |

## Cable Installation

Care must be taken to prevent cables coming into contact with moving parts such as control wires, or levers, or sharp edges of fittings or ducts or other equipment.

Where practicable it is advisable that the lengths of cable should exceed the minimum necessary to meet installation requirements by approximately 2 in., so that if end breakage occurs the connection can be re-made without using new cable. The excess lengths at the ends of the cable should be properly secured.

No splicings, twistings, solderings, or any other joints are permitted in a length of cable.

There must be no risk of oil, petrol, or dope coming into contact with the cables, which must be installed in such a way as to not be liable to accidental damage by persons getting into or out of, or moving about, or in the course of flying in, or maintaining, the aircraft.

Wherever necessary, cables must be protected from the effects of weather, sea water, dampness, or other atmospheric or similar deleterious conditions.

The progressive effects of continuous vibration must be carefully guarded against. The cables should only be taken through bulkheads, fairings, fabric, and the like by means of adequately bushed holes.

The installation should provide for adequate support to the cables throughout their length, unnecessary hangings, loops, or slacknesses, or undue stressing being strictly avoided.

The fixings for cables, ducts, cleats, and the like, or any other item of the electrical equipment must not involve the drilling of holes or the making of passage ways which are liable to weaken any part of the aircraft structure.

Cable ends must be properly finished off as described hereafter and whilst being securely fixed in their terminals or other appropriate fittings, must not be under any mechanical stress; due allowance should be made for expansion and contraction, and for torsion of the structure.

The various items of equipment should as far as possible be grouped

together on one side of the aircraft, to simplify wiring and connecting up and to avoid wiring being taken across the fuselage or hull.

Cable runs for general lighting and heating circuits must not be run in common ducts with wireless, ignition, or other circuits and must in fact be separated as far as available space permits.

Serious interference with W/T and direction-finding apparatus may result from the close proximity of other electrical systems. The cables must be readily accessible throughout their length in order to facilitate inspection or replacement.

Cables may be carried in systoflex or in open metal ducts or tubular fairings or conduits. Open ducts designed to carry a number of cables should be provided with front covers or narrow clips which can be sprung on the edges of the ducts. Such ducts are sometimes lined with sponge rubber, which lightly pressing on the cables when the trough is closed, prevents movement.

It is advisable to stencil, or mark with a coloured band in accordance with the key as already given, all closed troughs and ducts.

Tubular fairings and circuits must have clean, smooth bores. Ducts and fairings should be bell-mouthed bushed to prevent abrasion cutting through the cable insulation, with consequent short circuiting. Metallic cable conveyances as mentioned above should of course be "brought in" the bonding system of the aircraft where applicable.

To facilitate erection and dismantling the aircraft, suitable provision should be made for severing and re-uniting the electrical circuits at the junction of detachable components. A terminal block is suitable for this purpose, provided it is easy of access.

On aircraft with folding wings the terminal block should be placed near the hinge joint, and the cable arranged in such a way as to obviate any detachment, fraying, or detrimental effect.

Adequate precautions are to be taken to prevent the twisting of cables whilst being drawn through tubes or fittings; such twisting leads to the formation of kinks and possible fracture.

If it is ever necessary to leave cable ends loose they should not be left bare. Each end should be protected by wrapping with insulating tape. Bare ends should never be twisted together. Along spars, struts, longerons or decking, where a clear run may be obtained without the cable fouling metal fittings, the cable or cables may be attached with aluminium cleats. These may be formed by lengths of aluminium strip bent to shape as shown in Fig. 107 and secured at each end with a small woodscrew. The cables where they pass beneath the cleat should be armoured against abrasion by being covered with a case of rubber or systoflex (insulation-impregnated braided cotton) strip or tube. Where more than one cable is secured by a single cleat the set is wrapped together in a protecting strip or passed through a common length of systoflex tubing. Where the cables pass transversely across a spar, strut, or longeron, the protective covering is carried $\frac{1}{2}$ in. beyond each edge.

Through decking and solid ribs where the cable is taken through a structural component of the aircraft it is protected by a bush of petrol-resisting rubber piping of sufficient length to project for $\frac{1}{2}$ in. on each side. The bush is a comfortable fit for the cable before assembly and a snug fit in its hole.

Should any difficulty be found in drawing the cable through its bush, French chalk is the only lubricant permissible.

It is impossible, as a rule, to carry a cable along the face of the main spars inside planes owing to its fouling bracings and other metal fittings;

it is therefore often suspended to the rear of a spar in straps of the type in Fig. 108. The free ends of the strap are secured to the various ribs by small screws or fastenings.

Through fabric the cable is passed through a leather washer sewn to a patch: this patch is doped to the fabric so that the washer is located between the fabric and the patch.

Covered components should show the presence of internal electrical fittings or attachments by bearing upon inspection doors or patches an inscription such as "Electrical connections here," etc.

Between fin and tail plane the cable is run in the manner shown in Fig. 107 and is taken up the rear vertical spar, often terminating in a plug socket unit clipped to the side of the spar on the outside of the fabric; from the plug a length of cable is run inside the fabric of the rudder to emerge again close to the tail navigation lamp mounting. A short loop is left between the plug and where the cable enters the rudder of sufficient length to permit free movement of the rudder. The loop and the portion of the cable close to the navigation tail lamp fitting which is outside the rudder is enclosed in a length of rubber or systoflex tubing, the ends of which are served with prepared twine to prevent the entry of water.

Where cables are taken along tubular structural members of metal aircraft they are secured by being bound with six turns of 22 S.W.G. tinned-copper wire; the individual turns of the binding are soldered together in two places across a diameter of the tube so that the heat of the soldering does not damage the insulation of the cables; the cables are protected against abrasion as already described in the case of installation, "along spars, struts," etc.

Where cables cross members of all-metal aircraft they are secured by cleats of the type shown in Fig. 107. These cleats are wired in place and the cables protected against abrasion in the usual way. Cleats must not be secured to hollow or built-up wooden spars or other components likely to be split or damaged by their being secured with wooden screws. If possible the cleats should be fitted only at places stiffened by packing blocks, and the cables should be supported at intermediate points by doped fabric or other suitable slings.

Live wires in the vicinity of fuel tanks and pipes must be suitably encased.

All cable ends at terminals should be distinctly marked: this is often done by coloured sleeving and sleeves bearing the name of polarity and service.

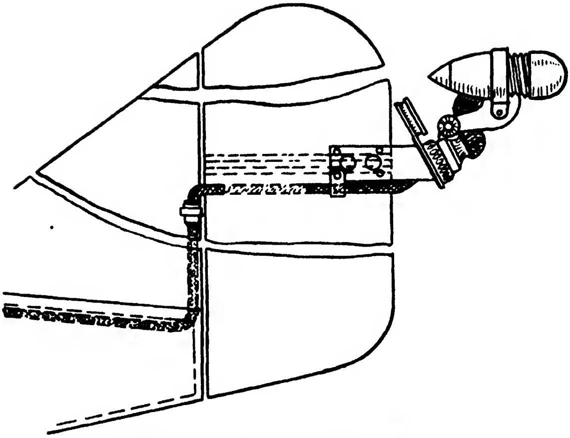
When making-off ends of cables, no frayed ends should be left out, all strands being in good contact. The following is a method of preparation—

Cut the outer covering back 1¾ in., fit the identification sleeve over the outer covering, serve with sailmakers twine or thread, cut the inner covering back according to the size of terminal screw, make and form the bare copper end into an eyelet, then bind the shank end with insulating covering tape or thread of the correct colour. Care should be taken that no strands are severed during insulation stripping.

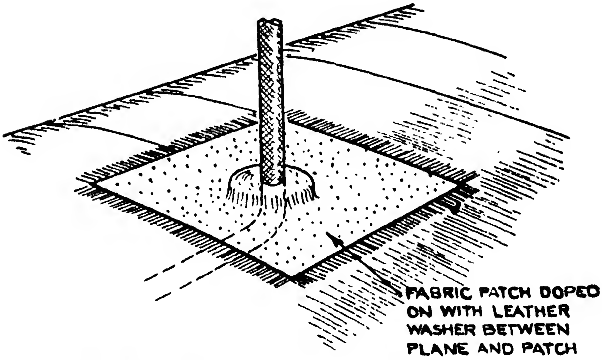
Except in special cases soldering together of the individual strands of a flexible cable is not permissible, as strands may be easily broken and the general flexibility of the cable at the soldered joint is lost.

Soldered cable ends may be required where—

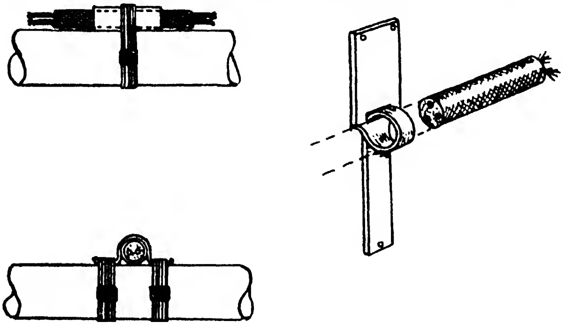
1. Slotted terminals are employed with an inside screw pressing on the cable ends; in such cases a soldered shank should be formed on the end of the cable.
2. Small eyelets with lugs are used.
3. Lugs with thimbles are used, as on some plugs and sockets.



METHOD OF RUDDER WIRING.



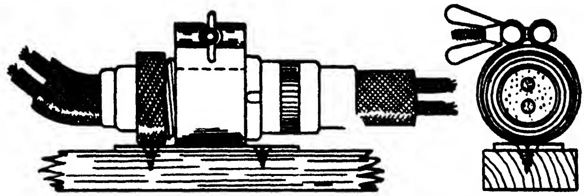

METHOD OF BRINGING CABLES THROUGH FABRIC.



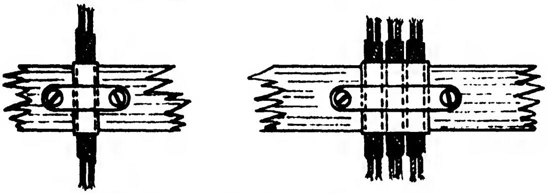
METHOD OF WIRING IN ALL METAL AIRCRAFT.

METHOD OF CARRYING CABLES THROUGH PLANES.

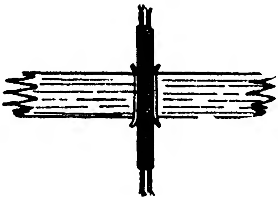
Fig. 107



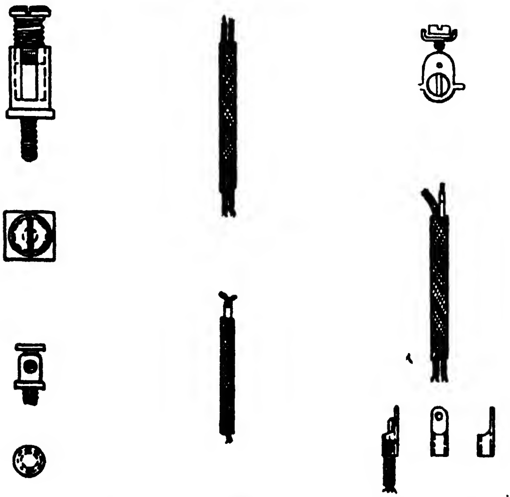
METHOD OF CLIPPING CIRCULAR PLUG AND SOCKET CONNECTORS IN FUSELAGE, WINGS, ETC:



METHOD OF CLEATING ON BATTENS.



METHOD OF BRINGING CABLES THROUGH WOOD.



METHOD OF FIXING CABLE ENDS AT TERMINALS.

Fig. 108

When soldering cable ends to plugs and sockets such as for the generator, care should be taken to apply as small an amount of heat as is necessary for a good joint. Heat destroys the properties of ebonite and bakelite commonly used for plugs and sockets. The fit of the plugs and sockets should be checked after soldering; it will often be found that slackness in the bases, requiring taking-up with a proper tool, has followed this operation.

For soldering, a non-corrosive type of flux, such as resin, should be used; at the conclusion of the operation connections and adjacent ebonite parts which tend to become adhesive and attract metal dust (with a resultant low megger test reading) should be washed in warm water and dried.

Soldered cable ends are not permitted with—

1. Cylindrical holes and grub screws.
2. Terminals consisting of a circular hole with diametral slot, a central screw with large head and a washer.

A soldering thimble consisting of a thin copper tube passed over the end of the cable and spot soldered is used on all items of electrical equipment where the grub screw method of attachment of the cable is employed.

*Examination* consists, of course, in the general verification of the foregoing. Cables should be examined periodically to ensure that the insulation has not been damaged by contact with moving parts or persons and has not deteriorated from petrol, oil, sea water, dampness, wear and tear, or other cause. The cleating should be inspected to see that no damage has occurred as the result of vibration. The insulation tests which are later described will also give an indication of the general condition of the cables. See that—

(*a*) These general service circuits are, as already instructed, kept as remote as possible from other circuits especially W/T and D/F, in order to reduce risk of interference with external communications; and that in no circumstances have common runs or ducts been adopted.

(*b*) Where aluminium or duralumin tubes or ducts are used for the accommodation of cables they are suitably protected against corrosion.

(*c*) All wiring is suitably marked as necessary to facilitate identification.

(*d*) All cables are free from joints of any description except where terminal blocks or other approved means, adequately protected, are employed.

(*e*) Where cables having an absorbent covering are used and any part of the cable is or could come in contact with the aircraft structure (conduits or ducts are not regarded as parts of the structure) such parts of the cable are separated from the aircraft structure by a non-hygroscopic medium. (Systoflex or material of a like nature is suitable for this purpose.)

(*f*) All cable ends are properly prepared.

(*g*) The rubber and other outer coverings of wires and cables are not allowed to come into contact with dope, petrol, oil, or similar preparations having a deleterious effect thereon.

(*h*) A non-corrosive flux has been used for any soldering.

(*i*) The conductors or cables are free from stress where they are attached to terminals or other fittings, and that the body of the cable is securely clamped at a point as near as possible to the terminal or fitting by means of a suitable clip.

(*j*) Where an insulating separator is required between two metallic bodies, no process which tends to reduce the efficiency of the insulator as such is used. The use of any metallic oxide paint or metallic dope is prohibited. (Soaking of the insulator in paraffin wax or varnish is permitted.)

## 29. GENERAL ELECTRICAL PARTS, COMPONENTS, AND ACCESSORIES

### Switches

There are three kinds of switches in common use, knife, rotary, and tumbler; they are used for making and breaking electrical circuits. They should be arranged easy of access but beyond the possibility of accidental operation. The influence of gravity upon knife switches should be to make them remain off when "open," and not fall into contact.

The action of most switches is accelerated by the incorporation of spring "snap" devices which prevent prolonged arcing but nullify any hesitancy of operation.

The switches should be of ample proportions to deal with the current in the particular circuit, and all movable current-carrying parts should make good electrical contact. There should be no sloppiness in jaws or hinges; faulty contact will cause burning of the parts and result in flickering or failure of the service controlled.

### Fuses

Fuses must be installed in all electrical circuits other than engine starters and magneto ignition. They must be of the enclosed type and projected against accidental damage and the terminals against accidental contact; they must be suitable for the kind and size of circuit into which they are inserted to protect. Fuse boxes, groups, or items, should be located where the fuses can be attended to and replaced easily. Fuses should be examined for signs of overheating, which may be due to overloading of the circuit or to poor electrical contact with the fuse clips. A blown fuse should be replaced by one of the same current capacity after having investigated the cause of the blowing. Heavier or lighter duty fuses than the correct ones would be dangerous in a circuit: the latter will readily blow and the former probably cause rupture of the circuit.

Terminal blocks and distribution boxes usually have a base of insulating material upon which are mounted the terminals to which the cables are attached for the linking up of the various circuits. The terminals should be properly separated and at the correct distance apart. The screwed devices should bear well upon the cable ends and be secured so they will not slack off. The terminals should be kept covered to prevent damage and accidental earthing or short-circuiting of the phases by conductive material coming into contact with them.

### Plugs and Sockets

Should make good electrical contact, cable ends being securely attached to their terminals. Points of exit and entry of the cables should be examined as regards wear and tear. Neither fuses nor plugs and sockets should be put into or taken out of circuit with the current on. The circuit should be broken by switch and only "made" again when the fuse or plug has been inserted.

### Voltmeters and Ammeters

These are not normally repairable outside the maker's factory. The cable connections to the instruments should be examined to ensure that they are correctly, firmly, and securely connected. Any zero error should be corrected by means of adjusting screws where fitted.

### Navigation Lights

Are usually so constructed that they can be easily removed from the aircraft when not required. A plug is usually embodied in the base of the lamp, which is inserted into a socket permanently fixed to the aircraft, the socket being connected in the electrical system. The pins should fit the sockets in such a manner as to ensure good electrical contact, and the lamp fitting must be quite secure when fixed in position, the fixing gland nut being lubricated occasionally to prevent tightness. A weather-proof cap should be fitted over the socket when the lamp fitting is removed. The lights, green starboard, red port, and white tail (white head, also, in the case of aircraft under way on water) should be kept clear and unobscured.

Navigation lights must be tested for illumination, alignment, and angle of visibility. If the illumination is doubtful the cause is probably poor electrical connection in the plug and socket fitting or the lamp may be aged. If all lamps show poor illumination it may be due to low voltage at the battery or to a bad switch contact. Navigation lights should always be fitted with the correct lamp bulbs, otherwise the required range of vision may not be obtained.

In craft of less than 65 feet span one or more lamps centrally situated may take the place of those here mentioned.

### Identification Lamps and Switchboxes

The glasses of the lamps should be clean. Seating rings should be in good condition. Covers should be secured tightly by their clamps. The switchboxes should be maintained in good working order. Where applicable the key spring should be adjusted as required and the fulcrum of the morse key occasionally oiled with a drop of machine oil. The key contacts should be kept clean and flat; if the points become burned or pitted they should be cleaned with a fine file or emery paper. The switch contacts should be cleaned periodically by wiping with a vaselined rag.

### Landing Flares

The ignition circuit must include a double-pole master switch or double-pole firing push buttons with long travel and guarded against accidental operation; or it must incorporate some other approved arrangement that will guard against accidental operation of the flares.

The wiring should be arranged to minimize the risk of its becoming energized by other circuits in the event of an accident.

The flares must be mounted upon proper brackets, the construction and position of which must be such that the glare will not interfere, directly or by reflection in the windscreen, with the pilot's vision, and that the flame will be prevented from overheating the wing or aileron fabric when the aircraft is in flight or standing on the ground. If necessary, metal sheathing must be used as a protective medium.

Flares should be examined for apparent swelling of the content, deterioration of the outer case, and entry of water or any foreign substance through the sealing compound of the fuse element at the top of the flare. An electrical continuity test should be made to ensure that the fuse is intact. Flares or igniters should not be used after the date specified thereon. Flares should be stored under suitable conditions when not in use and should be protected from weather, dampness, and undue heat. Before a flare which has been carried is returned to store, it should be wiped with a dry cloth. The practice of carrying an unused and unprotected flare in its bracket for any considerable period of time is inadvisable;

the effects of damp atmosphere and rain, especially under flying conditions, are harmful, and in an extreme case may result in either dangerously irregular burning or total failure upon attempts of ignition being made. Flares should not, therefore, be fitted to the aircraft until immediately before a particular flight upon which it is anticipated they will be required. Owing to the possibility of accidental ignition it is advisable that flare leads should be disconnected before placing the aircraft in an hangar.

### Typical Landing Flare Bracket Used on Seagoing Aircraft

The landing flare bracket is designed to release the flare, when burning, just behind the actual landing point on the water, to avoid risk of the flare igniting oil or fuel under the machine when it comes to rest. The release is only a matter of seconds before landing. To fit the flare, insert the lugs into the contact holder, fit the hook of the wind vane on to the flare loop and pass the release strip through the slot in the guide and secure the end by the wing nut. When burning, the heat will release the strip from the flare, and the wind vane, kept in an upright position by wind pressure, will hold the flare. On losing speed the wind vane will drop forward until, before the machine actually lands, it drops sufficiently to release the flare from the bracket.

Care should be taken when testing these fuses not to use a lamp taking a greater current than ·15 of an ampere, otherwise there is a danger of igniting the flare.

### Landing Lamps

Are usually of a special design to suit a particular aircraft. They are, of course, on the accumulator circuit to prevent fading as the aircraft loses speed.

### Lamp Fittings

The lighting arrangements should be kept clean. Lamp bulbs should be a good fit in their holders. Bulbs which show signs of blackening should be replaced.

### Inspection Lamps

Examine the insulation of the wandering lead; the lead should be replaced if showing signs of abrasion.

### Dimmer Devices

Where these are fitted, the rheostat should be tested for good contact between the switch arm and the resistance wire. A steady variation in light should be obtained as the dimmer is moved over its range of operation.

### Heating Arrangements

Examine the apparatus for general condition. See that the elements are sound. Flexible leads should be in good condition with no signs of abrasion or stress at any of the plugs and socket fittings. The plugs and sockets should fit in a manner that will ensure good electrical contact. Devices which may be incorporated for preventing the accidental pulling apart of the connected plugs and sockets should be in good order. Any signs of over- or underheating should be immediately investigated. The surroundings adjacent to such heating arrangements should be adequately insulated against fire and scorching, and such insulation should be well maintained. No inflammable material may be within the vicinity and no

petrol or the like carried thereabouts whether in pipes, containers, or otherwise.

The various circuits should be tested separately for continuity. The current consumption of each section should be checked if any defect is suspected. If rheostats are incorporated they should be tested to ensure that heating can be reduced as required.

## General Tests

The full electrical equipment must be in accordance with the aircraft maker's instruction and diagrams. The installation should be tested from time to time. The tests comprise Insulation, Resistance, Correct connections and continuity, and Functioning.

The results of all tests should be recorded. By logging such periodic tests any gradual deterioration of the insulation can be detected and steps taken to prevent a breakdown. Apparatus which is connected to the fixed wiring of the aircraft such as generators, portable lamps, heaters, etc., should be tested separately for insulation.

The minimum figure for such apparatus is one megohm, for generators a minimum of 40,000 ohms is acceptable. The test must be made with a 500 volt megger or other suitable instrument and the insulation resistance of all circuits must be tested between poles and between each pole and earth. The minimum results to be obtained are, for wire circuits—

$$\text{No. of megohms} = \frac{20}{\text{number of points in the circuit}}.$$

The minimum value of the insulation resistance obtained by this formula is to be taken as 2 megohms. Switches (which must be closed in the circuit under test), terminal blocks, and other connected apparatus are to be counted as "points." The tests must be made with all switches in running position and the generators and batteries disconnected. All lamps must be removed from their sockets and all detachable plugs leading to heating units or other apparatus should be disconnected.

The insulation test in each instance must be maintained for not less than one minute.

(*Note.* Should the aircraft not be fitted with a voltage control box the leads stated will be found to be connected to a distribution terminal usually on or near the electrical control panel. The aircraft maker's appropriate diagram will indicate the position of this distribution terminal. The leads should be disconnected and the tests proceeded with as described.)

## Test for Insulation Between Poles of all Battery Circuits

All leads normally connected to the red terminal of the voltage control box are brought together and connected to one pole of the megger, the other terminal being connected to the negative terminal at the voltage control box-blue. If the figure obtained as the result of this test is not satisfactory it will be necessary to separate the leads at the voltage control box and test each circuit separately until the faulty one is discovered. Action is then to be taken to trace and remedy the fault.

## Test for Insulation Between Poles of the Generator Circuit

This test is similar to the foregoing except that the megger terminals are connected between the bunched leads from the yellow terminal and the bunched leads of the blue terminals of the voltage control box.

### Test for Insulation Between Positives

This test is similar to that given "between poles" except that the megger terminals are connected between the bunched leads from the red terminal and the bunched leads from the yellow terminal of the voltage control box. It will be noticed that in this case the leads are components of different circuits and it will be impossible to arrive at a denominator for the formula; the figure 6 should therefore be assumed for the purpose.

### Test for Insulation Resistance to Earth

For the purpose of this test all wires connected to all terminals of the voltage control box are bunched together and connected to one terminal of the megger; the other megger terminal is to be placed in good contact with the general earth system of the aircraft. If the result is unsatisfactory it will be necessary to separate the various circuits and test each separately until all faults are located and rectified. It will be understood that for the purpose of the first three of the above tests it is necessary temporarily to disconnect the various leads from the terminals of the voltage control box, which must not be in circuit during testing.

The insulation resistance will vary with atmospheric and other conditions and the standard obtained may be higher than that mentioned.

### Testing for Correctness of Connections and Continuity

All wiring should be tested from point to point with a battery and lamp or bell, with suitable leads. The smaller sizes of cable should be placed under slight tension during the course of this test to separate possible broken parts which may be just touching.

Should this test indicate any fault it will not only be necessary to rectify it but the insulation tests must be repeated so far as the affected circuit is concerned.

### Functioning Tests

An accumulator of suitable voltage should be temporarily connected to the normal accumulator leads and all switches and other control items on the normal accumulator branch operated several times to ensure that each branch of the system is working satisfactorily and is unaffected by the working of any other circuits; this will test the accumulator side. To test all circuits on both branches, the accumulator should be connected as for the battery branch, but in this case the generator leads should be disconnected at the generator end, and the plunger of the battery cut-out held up by hand. In this test all circuits on both branches should be operative.

### General Remarks

Aircraft general electrical systems are Direct current; pressure is customarily limited to 14 volts to minimize fire risk and other dangers attendant upon the use of higher voltages; high current densities, however, occur, and care should be taken therefore that the size of all conductors is ample and that all joints are well made and have generous contact areas, otherwise heating will take place.

For reasons of the nature of the demand, to prevent whole or partial non-availability of essential lighting, etc., and to reduce the heavy discharge from one (the accumulator) in the case of slowing down or failure of the other (the generator) the load is derived from two sources—that of heating, etc., being the generator, and that of the navigation, signalling,

landing lights, etc., and any other service where continuity of supply is vital, being the accumulator. Generators, accumulators, wiring, conduits, runs, layouts, switch and fusing gear, electrolytes, insulation, joint boxes, protective treatment, or anything else should never be changed in type or anything added or taken away from the total system without reference to the aircraft maker. The compass is affected by the nearby presence of electrical apparatus and the possibilities of stray magnetic fields from apparatus or cables interfering with its correct functioning should be borne in mind. For example, the following are considered the minimum safe distances between the compass and such apparatus—

1. Kw. full load generator 6 feet; generator 500 watts full load 4 feet; generator 250 watts full load 3½ feet; voltage regulator 40 amps. battery load 3½ feet; twin cables carrying 40 amps. 1 foot; single cable carrying 40 amps. 8 feet; single cable carrying 20 amps. 6 feet; single cable carrying 10 amps. 4 feet.

Notices and signs concerning the electrical system should never in any circumstances be removed or obliterated.

No manner of work involving the shedding of metal filings, etc. the splashing of metallic paint, or the bestrewing of material which may act as a conductor of electricity, should ever be done in the vicinity of electrical gear without previously covering over such gear with a cloth, etc., which may be afterwards gathered and shaken clear of the aircraft.

Ample protection should be afforded all parts of electrical installation against water, petrol, oil, or spray.

(Figs. 96, 98–105, 107 and 108 in this chapter are reproduced from *A.P.* 1095, by kind permission of the Controller, H.M.S.O.)

# APPENDIX I

## CERTIFICATE OF SAFETY FOR FLIGHT

I HEREBY CERTIFY that I have this day inspected the above aircraft (including its instruments and equipment but exclusive of the engine(s) and engine installation and of the instruments relating thereto) and that I am satisfied that it is safe in every way for flight, provided that the conditions of loading specified in the certificate of airworthiness are complied with.

The time this inspection was completed was 0900 hours.

*Signed* Herbert Brown.

Ground Engineer "A" Licence No. 10008.

Date: *November* 30*th*, 1933 Time: 1030 hours.

(Extract from *Air Navigation Directions*)

# APPENDIX II

Serial No. 745

ADVICE AND RELEASE NOTE
Issued under Air Ministry Authority
Reference No. 654321/30

## Harry Jones's Aircraft Works, Ltd.
NORTHEASTCHESTER
ENGLAND

Telephone: 999 Telegrams: "AEROPLANES"

| Please note the following have been dispatched— | Contract No. |
|---|---|
| Consignee—<br>The Starland Aerial Transport Co., Ltd.<br>Lowland Aerodrome,<br>Nr. Highover,<br>Hants. | Order ref. No. ZA 313 |

| Item No. of Contract or Order | Description of Goods including Part and Drg. Nos. and/or Specn. No. | Quantity | Identification | Remarks |
|---|---|---|---|---|
| 5 | STRUT, INTERPLANE 194/AC.531 | 1 | 4J21 | Order Complete |
| 12 | PLATES, WIRING 2001/A3C 211 | 4 | 4J33 | |

CERTIFIED that the whole of the material and/or parts detailed hereon have been inspected and tested in accordance with the conditions of

*The Air Navigation Directions*

and the general requirements of the Director of Aeronautical Inspection and that they conform with the drawings and specifications relative thereto.

*Signed* K. N. RICHMOND,
*Chief Inspector*, HARRY JONES'S AIRCRAFT WORKS, LTD.

*Date:* November 23rd, 1933.

# APPENDIX III

## GLOSSARY OF AERONAUTICAL TERMS

*Abstracted by permission from "British Standard Glossary of Aeronautical Terms," copies of which can be obtained from the British Standards Institution, 28 Victoria Street, London, S.W.1.*

**Airworthy.** Complying with the prescribed regulations for a certificate of airworthiness.

**Ground Engineer.** An individual authorized to certify the safety for flight of an aircraft or parts thereof in accordance with the regulations for the time being in force.

**Nose Heaviness.** A tendency of an aircraft to pitch down by the nose in flight.

**Tail Heaviness.** A tendency of an aircraft to pitch down by the tail in flight.

**Flutter.** An unstable oscillation due to the interaction of aerodynamic and elastic forces upon the inertia of any structure.

**Air Speed.** Speed relative to the air, as distinct from speed relative to the ground.

**Indicated Air Speed.** The product of the air speed and square root of the relative air density ( $V_i$).

*Note.* This definition will agree with readings taken by a pressure head only until the effect of compressibility becomes noticeable.

**Range.** The maximum distance an aircraft can travel under given conditions without refuelling.

**Streamline.** The path of a small portion of a fluid, assumed continuous, moving relatively to a solid body. The term is commonly used only of such paths as are not eddying, but the distinction should be made clear by the context.

**Aeroplane.** A flying machine with fixed wings.

**Amphibian.** An aeroplane provided with means for normally rising from and alighting on either land or water.

**Landplane.** An aeroplane provided with means for normally rising from and alighting on land.

**Seaplane.** An aeroplane provided with means for normally rising from and alighting on water.

**Float Seaplane.** A seaplane provided with floats as its means of support on water.

**Flying Boat.** A seaplane of which the main body or hull is also the means of support on water.

**Monoplane.** An aeroplane or glider with one main supporting surface.

**Multiplane.** An aeroplane or glider with two or more main supporting surfaces one above another.

**Biplane, Triplane.** *Note.* Monoplane, Multiplane, Biplane, and Triplane are also used as adjectives associated with a particular component, e.g. Biplane rudder, Triplane tail, etc.

**Pusher Aeroplane.** An aeroplane in which the airscrew is mounted in rear of the main supporting surfaces.

**Ship-plane.** Any aeroplane specially adapted for rising from and alighting on a ship's deck.

**Tractor Aeroplane.** An aeroplane in which the airscrew is mounted in front of the main supporting surfaces.

**Aerofoil.** A surface designed to produce an aerodynamic reaction normal to the direction of motion.

**Slotted Aerofoil.** An aerofoil having an air passage (or slot) rearwardly directed from its lower to its upper surface. This slot is so shaped that the portions of the aerofoil separated by it are themselves of aerofoil section. When the slot is forwardly located the portion forward of the slot forms an auxiliary aerofoil which may be rigidly attached to the rear portion or be capable of movement relative to it.

**Slat.** An auxiliary aerofoil forming the forward portion of a slotted aerofoil with forwardly located slot.

**Aerofoil Section.** The outline of the section of an aerofoil in a plane parallel to its plane of symmetry.

**Aileron Angle, Elevator Angle, Rudder Angle.** The angle between the chord of the movable portion of an aerofoil and the chord of the corresponding fixed surface.

**Angle of Incidence (Rigging).** The angle between the chord line of the main plane and the horizontal when the aeroplane is in the rigging position.

*Note.* Not to be confused with the true angle of incidence.

**Angle of Sweep-back.** The angular set back of the main planes relatively to the fuselage or hull.

**Dihedral Angle.** The angle at which both port and starboard planes of an aeroplane or glider are inclined upwards or downwards to the transverse axis. The dihedral angle is the acute angle between the span axis of either plane and the transverse axis. If the inclination is upwards the dihedral is positive.

**Tail Setting Angle.** The acute angle between the chord line of the main plane and the chord line of the tail plane. If the latter is at a greater inclination to the horizontal than the former the angle is said to be positive.

**Camber.** Curvature of a surface of an aerofoil.

**Chord or Chord Length.** The length of that part of the chord line which is intercepted by the aerofoil section.

**Chord Line.** The chord line is the straight line through the centres of curvature at the leading and trailing edges of an aerofoil section.

**Gap.** The distance between a plane and the one immediately above and below it.

**Leading Edge.** The forward edge of a streamline body or aerofoil. The structural member there situated.

**Overhang.** 1. The extent to which the wing tip of one of the two superimposed planes projects beyond the tip of the other.

2. The distance from the outer point of support to the tip of an aerofoil.

**Rigging.** The relative adjustment or alignment of the different components of an aerodyne.

**Rigging Position.** The position in which, with the lateral axis horizontal, an arbitrary longitudinal datum line is also horizontal.

**Span.** The overall distance from wing tip to wing tip.

Semi span. The distance from the tip to the plane of symmetry of an aerofoil.

**Stagger.** When one of two superposed planes is disposed ahead of the other, the planes are said to be staggered. When the top plane is ahead of the bottom the stagger is said to be positive.

**Trailing Edge.** 1. The rear edge of a streamline body or aerofoil.

2. The structural member there situated.

**Wash-in.** Increase of angle of incidence towards the wing tip.

**Wash-out.** Decrease in angle incidence towards the wing tip.

**Airframe.** An aeroplane with the engine(s) removed.

**Doping.** Treatment for the purpose of protecting tautening, strengthening or rendering airtight a surface.

**Aero-structure.** The supporting and controlling surfaces of a flying boat.

**Ailerons.** Movable flaps situated at or near each wing tip and designed to impart a rolling motion to the aerodyne by their rotation in opposite senses.

**Floating Ailerons.** Port and starboard ailerons so connected that, under the action of air moments, alone, they are free to take up an equilibrium without relative angular displacement. They are operated differentially in the normal manner through the control column.

**Balanced Surface.** A control surface which extends on both sides of the axis of the hinge or pivot in such a manner as to reduce the moment of the air forces about the hinge. The portion of the surface in the front of the hinge is referred to as the "balance" or "balance portion."

**Horn Balance.** The balance is confined to the tip of the control surface and extends beyond the fixed surface.

**Centre Section.** The central portion of the main plane (top or bottom).

**Elevator.** A movable horizontal surface for controlling the motion of an aerodyne in pitch.

**Fin.** A fixed vertical surface affecting the lateral stability of the motion of an aerodyne. When fitted at the rear end of the body it is termed the tail fin.

**Flap.** A hinge rear portion of an aerofoil.

**Levers.** Aileron Lever, Elevator Lever, Rudder Lever. The lever arm by which the control surface is connected to the actuating mechanism.

**Planes.** Main Plane. A supporting surface of an aerodyne, including ailerons.

**Rudder.** A movable vertical surface for controlling the motion of an aerodyne, in yaw.

**Servo Control.** A control devised to reinforce the pilot's effort by an aerodynamic or mechanical relay.

**Stub Plane.** 1. A short length of plane projecting from the fuselage or hull (usually forming a part thereof) to which the main portion of the plane is connected.

2. Projections from the hulls of flying boats to give lateral stability on the water.

**Tail Unit.** The combination of stabilizing and controlling surfaces situated at the rear of an aerodyne.

**Chine.** The extreme side member of the hull running approximately parallel to the keel in side elevation.

**Control Column.** The lever, or pillar supporting a hand wheel, by which the elevator and aileron controls are operated.

**Adjusting Gear for Aileron, Rudder Fin, or Tail Plane.** Mechanism provided for altering the trim of the control surface during flight.

**Rudder Bar.** The foot bar by means of which the rudder is operated.

**Rudder Pedals.** An alternative device to rudder bar.

**Alighting Gear.** That part of an aerodyne (other than the hull of a flying boat) provided for its support on land and water, and for absorbing the shock on alighting. In addition to the undercarriage, alighting gear includes subsidiary items such as tail skid, wing tip skids, and floats.

**Float.** A water-tight body giving buoyancy and stability on the water to a seaplane or amphibian and enabling it to take off and alight.

**Flotation Gear.** Emergency flotation appliances for landplanes.

**Step.** A break in the under-surface of a float or hull designed to facilitate take-off.

**Tail Skid.** A member taking the weight of the rear end of the fuselage on the ground.

**Tail Skid Bar.** The crosspiece on a steerable tail skid.

**Tail Skid Shoe.** A replaceable covering on the end of a tail skid to take the wear.

**Tail Wheel.** A small wheel sometimes fitted in place of a tail skid.

**Undercarriage.** That part of the alighting gear which embodies the main wheels, skids, or floats.

**Acorn.** A device introduced at the intersection of bracing wires to prevent abrasion.

**Strut.** A structural member intended to resist compression in the direction of its length.

**Drag Struts.** Struts incorporated in the framework of an aerofoil to carry the loads induced by the air forces in the plane of the aerofoil.

**Interplane Struts.** Vertical or inclined struts connecting the spars of a plane to those of the plane above.

**Jury Strut.** A strut inserted to provide temporary support for a structure. A common example is the strut used to support the wing structure of an aerodyne during folding.

**Wires.** *Drag Wires.* Wire or cables the principal function of which is to transfer the drag of the planes to the body or other part of the structure.

*Anti-drag Wires.* Wires to resist forces in the opposite direction to the drag.

**Incidence Wires.** Wires or cables bracing the main plane structure in the plane of a pair of front and rear struts.

**Lift Wires.** Wires or cable the principal function of which is to transfer the lift of the wings to the body or other part of an aerodyne.

**Anti-lift Wires.** Wires to resist forces in the opposite direction to the lift.

**Flying Weight.** The total weight of an aircraft at the beginning of a flight.

**Gross Weight.** The maximum flying weight of an aircraft permissible under the regulations obtaining.

*Note.* For Civil aircraft this is the maximum authorized weight shown on the Certificate of Airworthiness.

**Tare Weight.** The weight of an aerodyne complete in flying order with water in the radiators, but no crew, fuel, oil, removable equipment or pay load.

**Airscrews.** 1. Generically, all types of screw with helical blades designed to rotate in air.

2. Specifically, a power driven screw designed to produce thrust by its rotation in air.

**Pusher Airscrew.** An airscrew designed to produce compression in the airscrew shaft.

**Left-hand Airscrew.** An airscrew revolving counter-clockwise to an observer behind the aircraft.

**Right-hand Airscrew.** An airscrew revolving clockwise to an observer behind the aircraft.

*Note.* In the tractor system the "hand" of the airscrew is the same as that of the engine, but in the pusher system it is the opposite.

**Variable Pitch Airscrew.** An airscrew whose blades are so mounted that they may be turned about their axis to a desired pitch while the airscrew is in rotation.

*Note.* This term is not to be used for an airscrew whose blades are adjustable only when stationary.

**Blade Angle.** The acute angle between the chord of an element of an airscrew blade and the plane of rotation.

**Out-of-Pitch.** Having the blade angles of one blade different from those of the other(s) at the same radius.

**Boss.** The central portion of the airscrew by which it is attached to the airscrew hub or shaft.

**Diameter.** The diameter of the circle described by the tips of the blades.

**Disc Area.** The area of the circle described by the tips of the blades.

**Pitch.** Experimental mean pitch. The distance through which an airscrew advances along its axis, during one revolution when giving no thrust.

**Sheathing.** Thin sheet metal or other material attached to the tips and leading edges of wooden blades to prevent abrasion by water, sand, etc.

**Slipstream.** The stream of air discharged aft by a revolving airscrew.

**Spinner.** A streamline fairing fitted co-axially and rotating with the airscrew.

**Static Unbalance.** An airscrew is in static unbalance if, when concentrically mounted on a spindle supported by knife edges, it will not remain at rest in all positions.

**Torque.** The moment about the airscrew axis of the air forces on the airscrew.

**Windmill.** A device which by virtue of its translational motion relative to the air rotates and so develops power.

**Air Speed Indicator.** An instrument, the reading on which, subject to certain corrections, gives the speed of the aircraft relative to the air.

**Altimeter.** An instrument graduated to indicate height under specified conditions.

**Cross Level.** An instrument for indicating the direction of the resultant force on an aircraft in a transverse plane.

**Fore and Aft Level.** An instrument for indicating the direction of the resultant force on an aircraft in its plane of symmetry.

**Pressure Head.** A combination of pitot and static pressure tubes for use in conjunction with a differential pressure gauge for determining the speed of a current of air.

**Pitot Tube.** A tube with an open end facing a current of air.

**Static Pressure Tube.** A tube with lateral apertures designed to ensure that the pressure in it shall be static.

**Turn Indicator.** An instrument for indicating the deviation of an aircraft from its course to port or starboard.

**Compass.** An instrument for indicating, subject to certain corrections, the angle in the horizontal plane between the true or magnetic meridian and the longitudinal axis of an aircraft.

**Aircraft Landing Flare.** A pyrotechnic flare normally attached to the underside of an aircraft to enable the pilot to illuminate the earth's surface when alighting.

**Aircraft Lighting.** The system of lighting on an aircraft.

**Navigation Lamp.** A lamp on an aircraft for indicating its position and direction of motion.

**Riding Lamps.** Lamps displayed by aircraft at anchor or when moored.

**Signalling Lamp.** A lamp for making visual signs.

**Compass Base.** An area provided with means for orientating aircraft to facilitate the compensation of their compasses.

**Drogue.** A sea anchor consisting of a conical sleeve, open at both ends, used to check the way of an aircraft.

## DATE OF ISSUE

This book must be returned within 3/7/14 days of its issue. A fine of ONE ANNA per day will be charged if the book is overdue.